KNIGHT'S
MODERN SEAMANSHIP

Robert William Martin Jr.

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MODERN SEAMANSHIP

AUSTIN M. KNIGHT
LATE REAR ADMIRAL
UNITED STATES NAVY

FOURTEENTH
EDITION

REVISED BY
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ASSISTED BY
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Preface to the Fourteenth Edition

This revised edition of *Knight's Modern Seamanship* has been compiled by a team of experts and specialists. In coordinating this team with me, Master Chief Journalist William J. Miller, USN (Ret.) has been of major assistance.

Part III, *Rules of the Nautical Road*, has again been revised by Lt. Cdr. Alfred Prunski, USCG. Captain E. T. Harding, USN, Director U.S. Naval Weather Service, has reorganized and brought up to date Part IV, Weather.

Cdr. R. J. Alexander, USN, a career Naval oceanographer, has contributed an important new chapter on oceanography as well as a new chapter on navigation. These two chapters represent a major part of the significant new material in this edition.

Other contributors were:

Cdr. Emil Saroch, Jr., USN—Ice seamanship
Cdr. C. H. Blair, USN—Fishing Craft (sketches by Lt. W. D. Ansel, USNR)
Cdr. C. J. Burton, USN (Ret.)—Helicopter operations
Mr. John Movell of the Bureau of Ships—Knots, splices, rope, etc.
Mr. Bernard Hartley of MSTS—Cargo handling
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Cdr. G. G. Bailey, USN—Shiphandling
Cdr. W. H. Hibbs, USN (Ret.)—Shiphandling.

Appreciation must also be expressed to the following who served as advisors and consultants:

RAdm. John Harllee, USN (Ret.), Chairman of the U.S. Maritime Commission
RAdm. Gordon McLintock, USMS, Superintendent U.S. Merchant Marine Academy
Dr. Howard Johnson, Bureau of Naval Personnel
Capt. Albert Steinbeck, USN
Cdr. Franco di Giamberardino, Italian Navy

JOHN V. NOEL, JR.
Captain U.S. Navy (Ret.)

Preface to the First Edition

An attempt is made, in the following pages, to cover a wider field than that covered by most of the existing works on Seamanship.

The admirable treatises of Luce, Nares, and Alston, originating in the days when Seamanship was almost wholly concerned with the fitting and handling of vessels under sail, have preserved through later editions the general characteristics which they naturally assumed in the beginning. These treatises will never be out of date until the time, still far in the future, when sails shall have been entirely driven out by steam. It will hardly be denied, however, that the Steamer has long since established its claim to consideration in Seamanship, and that there is room for a work in which this claim shall be more fully recognized than in the treatises above referred to. The excellent work of Captains Todd and Whall, *Practical Seamanship for the Merchant Service,* deals more fully than either of its predecessors with the handling of steamers; but its point of view is, as its name implies, primarily and almost exclusively that of the Merchant Service.

Shortly after the present work was begun, a circular letter was addressed to officers of the Merchant Service and extensively circulated through the Branch Hydrographic Offices at New York, Philadelphia, Baltimore and Norfolk, requesting the views of the officers addressed.

The answers received to these questions were unexpectedly numerous and complete. More than forty prominent officers of the Merchant Service replied, many of them writing out their views and describing their experiences with a fullness of detail far beyond anything that could have been anticipated.

The thanks of the author are due particularly to the following for letters or for personal interviews covering the above points: Capt. W. H. Thompson, *S.S. Belgenland;* Capt. T. Evans, *S.S. Runo;* Capt. J. Dann, *S.S. Southwark;* 1st Officer T. Anfindsen, *S.S. Southwark;* Capt. J. C. Jameson, *S.S. St. Paul;* Capt. H. E. Nickels, *S.S. Friesland;* Capt. G. J. Loveridge, *S.S. Buffalo;* Capt. F. M. Howes, *S.S. Kershaw;* Capt. T. J. Thorkildsen, *S.S. Trojan;* Capt. Otto Neilsen, *S.S. Pennland;* Capt. H. Doxrud, *S.S. Noordland;* Capt. C. O. Rockwell, Clyde S. S. Co.; Capt. S. W. Watkins, *S.S. Montana;* Capt. Anders Beer, *S.S. Nordkyn;* Capt. J. M. Johnston, *S.S. Sardinian;* Capt. A. R. Mills, *S.S. Westernland;* Capt. J. S. Garvin, *S.S. Cherokee;* Capt. Robt. B. Quick, *S.S. El Cid;* Capt. Wm. J. Roberts, *S.S. New York;* Capt. T. Richardson, *S.S. Noranmore;* Capt. E. O. Marshall, *S.S. Maryland;* 1st Officer H. S. Lane, *S.S. Mary-*

land; Capt. W. F. Bingham, *S.S. Marengo;* Capt. R. Gowing, *S.S. Greatham;* Capt. H. J. Byrne, *U.S.A.T. McPherson;* Capt. Paul Grosch, *S.S. Stuttgart;* Capt. Geo. Schrotter, *S.S. Belgravia;* Capt. F. C. Saunders, *S.S. English King;* Capt. Chas. Cabot, *S.S. Venango;* Capt. Chas. Pinkham, *S.S. Queen Wilhelmina;* Capt. A. Traue, *S.S. München;* Capt. W. Thomas, *S.S. Quernmore;* Capt. H. O. Nickerson, Fall River Line; Capt. Geo. Lane, Baltimore Steam Packet Co.

Important assistance was received from Naval Constructor W. J. Baxter, U.S. Navy, who prepared Chapters I and XVIII; and from Lieutenant E. E. Hayden, U.S. Navy, who contributed several Charts and much valuable information upon Meteorology, for Chapter XIX.

Chapter V was suggested by a paper, "Mechanical Appliances on Board Ship," by Captain Thomas Mackenzie, issued by the London Shipmasters' Society as No. 29 of their valuable series of publications.

It would be impossible to mention all the naval officers who have assisted the author with criticism and suggestions; but acknowledgment is especially due to Lieut.-Commander A. W. Grant, Lieut. John Hood, Lieut. W. R. M. Field, Lieut. John Gow, Lieut.-Commander W. F. Worthington, Commander J. E. Pillsbury, Lieut. V. S. Nelson, Lieut. Ridgely Hunt, and Chief Boatswain W. L. Hull, all of the United States Navy.

Above all, acknowledgment is due to Chief Boatswain C. F. Pierce, U.S. Navy, who not only assisted in the preparation of many parts of the text, but prepared sketches for fully one-half the illustrations of the volume.

AUSTIN M. KNIGHT.

United States Naval Academy,
April 1, 1901.

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Part I

THE SHIP

1

Ships

Ships are classified in several ways: by the materials of which their hulls are built, by their methods of propulsion, by their ownership, or by their uses. It seems handiest and most rational to classify them by their uses. Even in this method of classification we are limited by the fact that many ships are used for more than one purpose, and we must fit our grouping to the primary or principal use of each ship.

The broadest classification of ships by use distinguishes them as MEN-OF-WAR and MERCHANT SHIPS. These were originally the same; each vessel carried on its business of trade or transportation and was at the same time prepared to attack or to defend itself against any enemies encountered. As time went on, nations found it cheaper and more efficient to have certain public vessels designed and armed for warlike purposes only, and to give them the primary function of destroying hostile ships and the protection of their own unarmed merchantmen. Because of new concepts of war and of new inventions, such as the submarine and the airplane, the pendulum has now swung partly back to the point where some merchant ships are built to carry a certain amount of armament and do carry it in wartime.

Men-of-war and merchant ships together are major components of seapower—and upon seapower rests in large part the security as well as the prosperity of the United States of America and of the Free World. Seventy percent of the earth's surface is water; in one sense we and our allies in North America and in South America are islands, surrounded by vast oceans. We must control these oceans not only to provide ourselves with the raw materials for industry, which we need, but to provide weapons and food for our allies in times of emergency. The oceans are also our shield and bulwark—in their depths are concealed nuclear submarines armed with POLARIS missiles—an invulnerable force to deter our enemies from attack.

It is well to remember that insofar as many important strategic raw materials are concerned the United States is a have-not nation. Only ships can bring us such metals as tin, cobalt, bauxite, and manganese, to mention but a few, that are so vital to our factories.

In keeping the sea trade routes open, in quelling local disorder, and in showing the Flag throughout the world, our country needs ships, both merchant and men-of-war. The Merchant Marine and the Navy are partners in maintaining American seapower.

TABLE 1.1. UNITED STATES NAVY SHIP TYPES

WARSHIPS

Aircraft Carriers:	
CVA	Attack Aircraft Carrier
CVAN	Attack Aircraft Carrier (Nuclear)
CVS	ASW Support Aircraft Carrier
Cruisers:	
CA	Heavy Cruiser
CAG	Guided Missile Heavy Cruiser
CG	Guided Missile Cruiser
CGN	Guided Missile Cruiser (Nuclear)
CLG	Guided Missile Light Cruiser
Destroyers:	
DD	Destroyer
DDG	Guided Missile Destroyer
DDR	Radar Picket Destroyer
DL	Frigate
DLG	Guided Missile Frigate
DLGN	Guided Missile Frigate (Nuclear)
Submarines:	
SS	Submarine
SSN	Submarine (Nuclear)
SSBN	Fleet Ballistic Missile Submarine (Nuclear)
SSG	Guided Missile Submarine
SSGN	Guided Missile Submarine (Nuclear)

(*Representative ship types listed to end of Table*)

AMPHIBIOUS WARFARE SHIPS

AGC	Amphibious Force Flagship
AKA	Attack Cargo Ship
APA	Attack Transport
APD	High Speed Transport
APSS	Transport Submarine
LPD	Amphibious Transport Dock
LPH	Amphibious Assault Ship
LSD	Dock Landing Ship
LST	Tank Landing Ship

MINE WARFARE SHIPS

MCS	Mine Countermeasures Support Ship
MHC	Minehunter, Coastal
MSC	Minesweeper, Coastal (Nonmagnetic)
MSO	Minesweeper, Ocean (Nonmagnetic)

PATROL SHIPS

DE	Escort Ship
DEG	Guided Missile Escort Ship
DER	Radar Picket Escort Ship
PCH	Submarine Chaser (Hydrofoil)
PGM	Motor Gunboat
PTF	Fast Patrol Boat

COMMAND SHIP

CC	Command Ship

AUXILIARY SHIPS

AD	Destroyer Tender
ADG	Degaussing Ship
AE	Ammunition Ship
AF	Store Ship
AFS	Combat Store Ship
AG	Miscellaneous
AGB	Icebreaker
AGDE	Escort Research Ship
AGEH	Hydrofoil Research Ship
AGMR	Major Communications Relay Ship
AGR	Radar Picket Ship
AGS	Surveying Ship
AGSC	Coastal Surveying Ship
AGSS	Auxiliary Submarine
AGTR	Technical Research Ship
AK	Cargo Ship
AKL	Light Cargo Ship
AKS	Stores Issue Ship
AN	Net Laying Ship
AO	Oiler
AOE	Fast Combat Support Ship
AOG	Gasoline Tanker
AP	Transport
AR	Repair Ship
ARC	Cable Repairing or Laying Ship
ARG	Internal Combustion Engine Repair Ship
ARL	Landing Craft Repair Ship
ARS	Salvage Ship
ARSD	Salvage Lifting Ship
AS	Submarine Tender
ASR	Submarine Rescue Ship
ATA	Auxiliary Ocean Tug
ATF	Fleet Ocean Tug
AV	Seaplane Tender
AVB	Advance Aviation Base Ship
AVM	Guided Missile Ship
AVP	Small Seaplane Tender
IX	Unclassified Miscellaneous

All photographs in this chapter are Official U.S. Navy photos unless otherwise specified.

U.S. NAVAL SHIPS

1.1. Terminology. The Navy's ships are classified in three general and broad categories: vessels, service craft, boats.

Vessels, as defined by Navy Regulations, comprise generally "the ocean-going ships and craft of the Navy, and such other water-borne craft as may be assigned this classification." *Service craft* are usually "water-borne utilitarian craft not classified as vessels or boats," and *boats* generally include "waterborne craft suitable primarily for shipboard and similar use."

Most U.S. Naval vessels in an active status are commissioned ships, having been formally placed in commission. Such a ship flies a commission pennant (or command flag) to indicate her official status. Service craft are usually placed "in service," rather than "in commission." Ordinarily they have no names, being identified by designation and hull number.

1.2. Classification. The Navy's ships and service craft are officially classified in a list prepared by the Office of the Chief of Naval Operations. This listing has three major categories: combatant vessels, auxiliary ships, service craft. Within the "combatants" are five sub-categories: warships (including aircraft carriers, cruisers, destroyers, submarines), amphibious warfare ships, mine warfare ships, patrol ships, and command ships (see Table 1.1). The ultimate mission of auxiliary ships and service craft is to support the combatant ships.

Combatant Vessels

1.3. Aircraft Carriers. The modern attack aircraft carrier (with its airplanes) and the task force built around it, is the heart of the Navy's striking power. Features of an aircraft carrier include: island superstructure

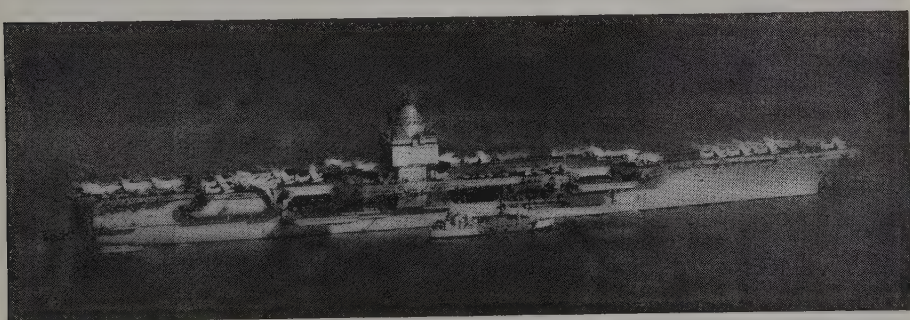


FIG. 1.1 *U.S.S. ENTERPRISE* (CVAN 65) NUCLEAR-POWERED ATTACK AIRCRAFT CARRIER

and angled flight deck, catapults for launching aircraft, arresting gear for aircraft recovery; hangar deck where planes are stowed and repaired, and large elevators for the rapid transfer of aircraft from deck to deck. The newer CVA are large enough to carry as many as 100 jet aircraft and accommodate over 4500 sailors of the ship's company and embarked air groups. In fact, the nuclear-powered *Enterprise* (CVAN 65) is the largest warship in the world. About half of the attack carriers now active have been commissioned since

1955. The rest date back to World War II, but have undergone extensive modernization since then.

ASW (antisubmarine warfare) support aircraft carriers (CVS)—launched during World War II as *Essex* class attack carriers—have been greatly improved under a program that began in the 1950's—the Fleet Rehabilitation

FIG. 1.2 *U.S.S. SACRAMENTO* (AOE 1) PROVIDES SUPPORT TO THE SMALLER *U.S.S. ROBINSON* (DDG 12) AND THE LARGER *U.S.S. HANCOCK* (CVA 19)

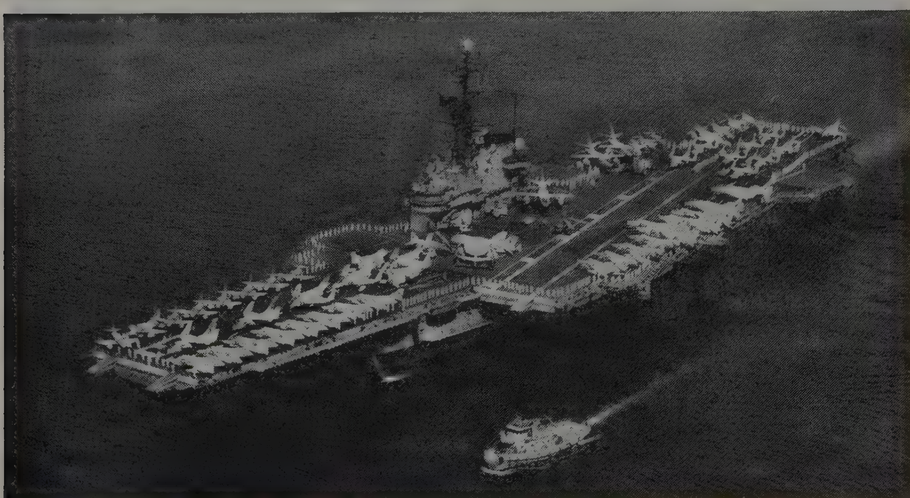


FIG. 1.3 *U.S.S. CORAL SEA* (CVA 43), MIDWAY-CLASS ATTACK AIRCRAFT CARRIER

and Modernization (FRAM) program. Most were redesignated ASW carriers. Armed with aircraft especially equipped to detect and destroy submarines, they are the backbone of the Navy's hunter-killer (HUK) groups.

1.4. Cruisers. Other than aircraft carriers, cruisers are the largest U.S. warships now active. They have a long cruising range, as the name implies, and are capable of high speeds. Guided missiles are the main weapons of a modern cruiser, enabling the ship to carry out its primary duty of providing antiaircraft defense to a task force.

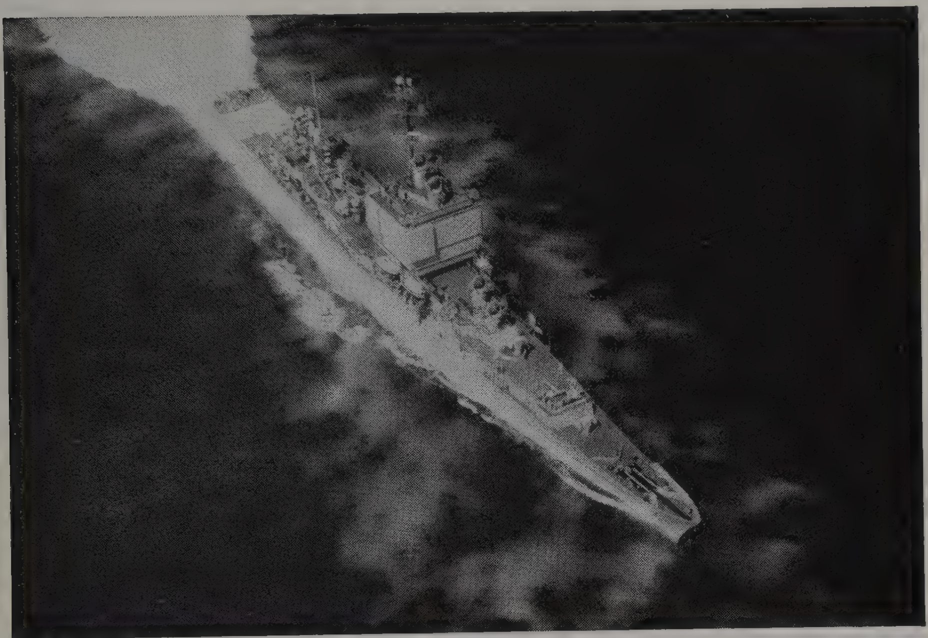


FIG. 1.4 NUCLEAR-POWERED GUIDED MISSILE CRUISER *U.S.S. LONG BEACH* (CGN 9)

Cruisers are also armed with conventional guns for use against enemy aircraft, ships and shore installations—plus ASROC—(antisubmarine rockets), helicopters, and torpedoes for use against submarines.

The *Long Beach* commissioned in 1961, is the Navy's first ship since World War II to be designed and built from the keel up as a cruiser. She is also the world's first nuclear-powered surface ship. Armed with Terrier missiles forward and Talos missiles aft, she has automatic systems for handling and launching both types.

The conventionally powered missile cruisers are called "double-ended and double-sided" types, since they have Talos launchers forward and aft, plus Tartar launchers to port and starboard. The CAGs are "single-ended," with Terrier launchers aft, 8-inch guns and 5- and 3-inch guns amidships. The CLGs are also single-ended, with Terrier or Talos missiles aft and 5- and 6-inch guns forward and amidships.

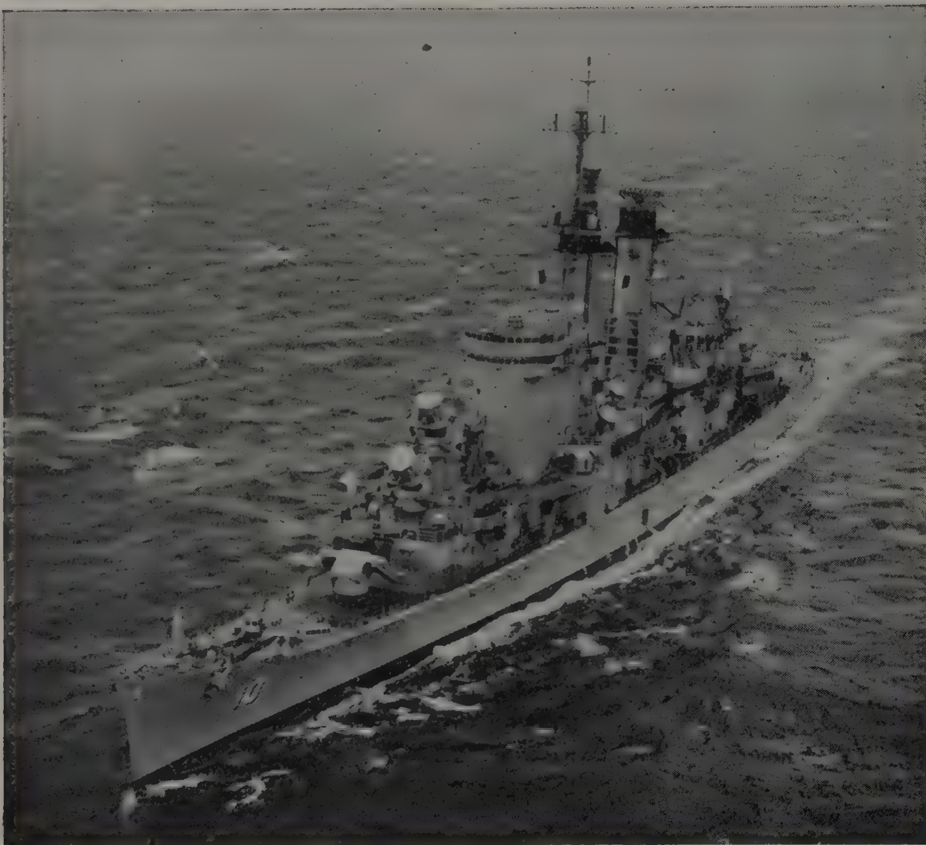


FIG. 1.5 *U.S.S. ALBANY* (CG 10), GUIDED MISSILE CRUISER

FIG. 1.6 A LITTLE ROCK-CLASS GUIDED MISSILE LIGHT CRUISER: *U.S.S. OKLAHOMA CITY* (CLG 5)

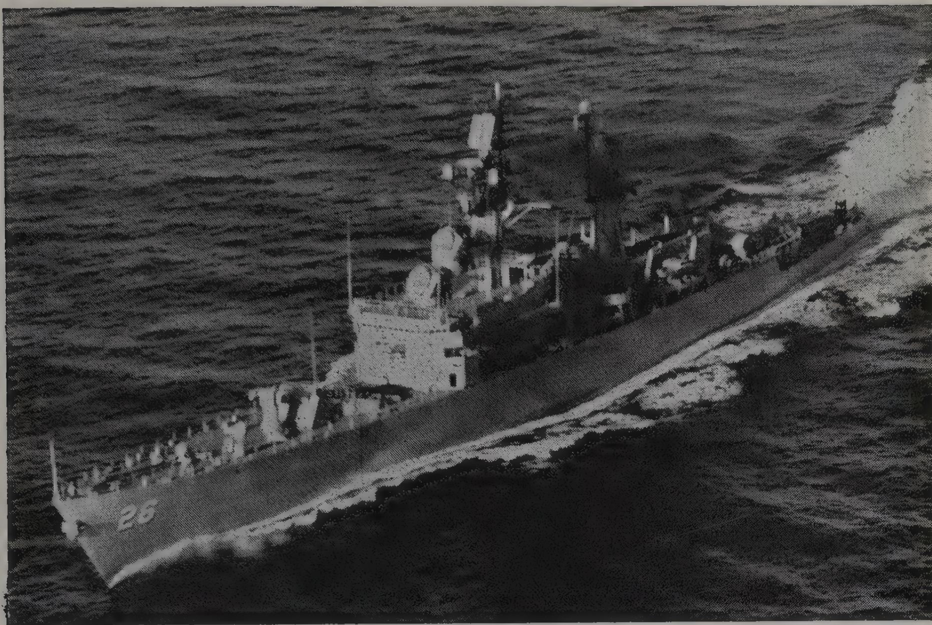


FIG. 1.7 LEAD SHIP OF HER OWN CLASS—GUIDED MISSILE FRIGATE *U.S.S. BELKNAP* (DLG 26)

1.5. Destroyers. Destroyers are not only the most versatile warships in the Navy, but also the most numerous. They are capable of speeds up to 35 knots, and depend on speed and maneuverability for protection. Their primary duty is anti-submarine warfare. However, they are useful in almost any situation—whether offensive or defensive action against surface ships, antiaircraft defense, gunfire support for amphibious operations, or patrol, search and rescue missions.

Largest ships in the destroyer group are frigates, which are as big as some World War II cruisers. The *Norfolk,* first ship of this type, was originally rated as a hunter-killer cruiser. The *Bainbridge* (DLGN 25) was commissioned in 1962, and two years later—with the *Long Beach* and *Enterprise*—cruised around the world without refueling . . . the first all-nuclear-powered task force.

Other frigate types are the *Mitscher* class DLs (which may be converted to DDGs), the *Farragut* class DLGs, and the *Leahy* class, most of which were commissioned in 1963. The first ship in a new class, *Belknap,* was commissioned late in 1964.

Numerous World War II DD are still active. Best known are probably those of the *Fletcher* class, which were virtually mass produced. Others are of the *Allen M. Sumner* and *Gearing* classes. The first post-war DDs were the *Forrest Sherman* class, commissioned in the late 1950's. Above the main deck their entire superstructure was made of aluminum. After these came the first large group of guided missile destroyers: the 23 ships of the *Charles F. Adams* class.

Another ship usually considered as part of the destroyer Navy is the escort ship (DE), although it is officially classified with the patrol ships. These DE were turned out by the hundreds during wartime to relieve full-size destroyers from convoy duty. Many were converted to high speed transports (APD) for amphibious work and, in the 1950's, some were beefed up with electronic gear into radar picket escort ships. Most of those still active are the *Edsall* class.

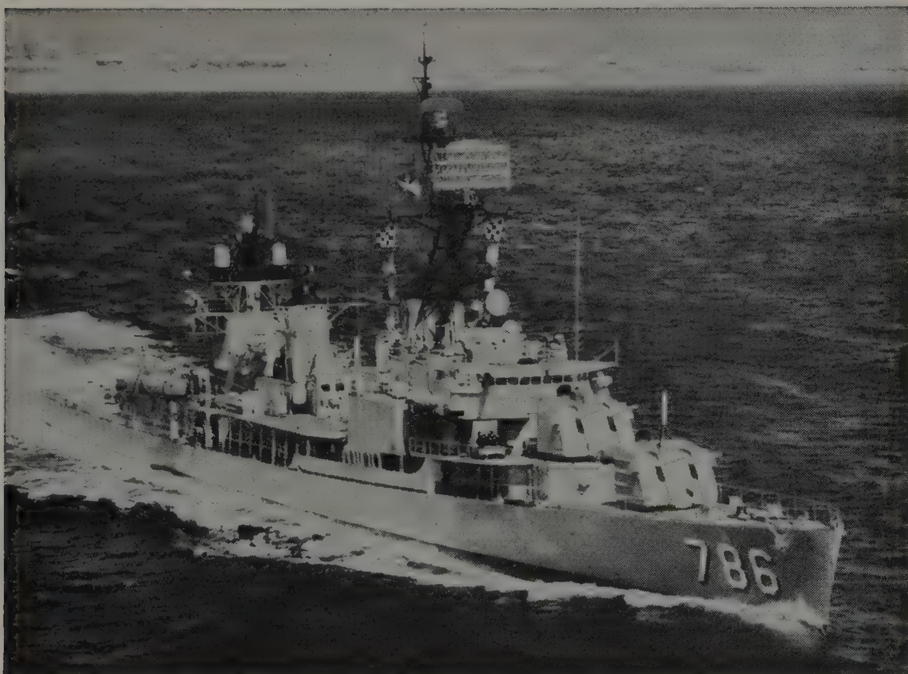


FIG. 1.8 *U.S.S. RICHARD B. ANDERSON* (DD 786)

The post-war DE include the *Dealey* and *Evans* classes built in the mid-1950's, the *Claude Jones* and *Bronstein* classes commissioned in the late 1950's and early 1960's. The *Garcia* class (10 ships) is the newest. Equally new is the 6-ship *Brooke* (DEG I) class of guided missile escort ship.

1.6. Submarines. Before nuclear propulsion and the Polaris missile, submarines were weapons for attacking an enemy at sea. To-day they can devastate inland targets thousands of miles distant.

By 1967 the Navy expects to have 41 SSBN in commission, each carrying 16 Polaris missiles and manned by "Blue" and "Gold" crews, which relieve each other after 60-day patrols. Of these ships, 31 will be of the *Lafayette* class, with 2875-mile range A-3 Poseidon missiles. The rest will be *Ethan Allen* class, with 1725-mile A-2 and *George Washington* class, with 1380-mile A-1 missiles.

To answer the threat of enemy ballistic missile submarines, the Navy is also stressing such nuclear-powered attack submarines as the 30 ships of the *Thresher* class, which began joining the fleet in 1962. These are designed for use against all types of enemy shipping, especially submarines. They are characterized by high submerged speeds, good ship control at periscope depth, and quiet operation.

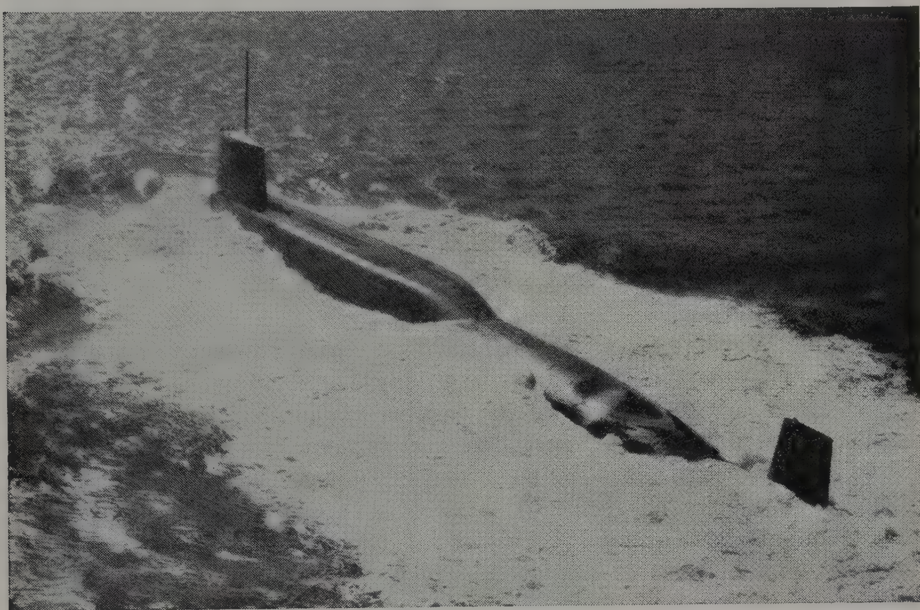


FIG. 1.9 FLEET BALLISTIC MISSILE SUBMARINE (NUCLEAR): *U.S.S. SIMON BOLIVAR* (SSBN 641)

No new conventionally powered submarines have been ordered since 1960. However many of this type are still active, including modernized World War II fleet types of the *Tench* and *Balao* classes.

1.7. Amphibious Warfare Ships. The amphibious assault ship (LPH) is an aircraft carrier designed to carry troops, cargo, and helicopters to a combat zone to seize a beachhead through vertical envelopment tactics. Another important type, also new, is the LPD. It can launch landing craft from its floodable well deck and helicopters from the platform over the well deck. The first LPD are closely related to those of the *Thomaston* class, which can carry more landing craft, but do not have helicopter facilities.

Other amphibious ships include the AGC, which is a command and communications ship for amphibious task forces; the LST which can land troops and vehicles on the beach through bow doors; the AKA, which can carry assault loaded cargoes to the scene of action and then send them ashore in the ship's own landing craft. Workhorse of the amphibious force is the attack transport (APA) which carries assault troops to the scene, and then, in her own landing craft, sends them ashore.

FIG. 1.10 *U.S.S. WHITFIELD COUNTY* (LST 1169)

1.8. Mine Warfare Ships. Most of the mine vessels now active are designed to locate and sweep mines, rather than lay them. Mine countermeasures support ships (MCS) are converted wartime amphibious ships used in the transportation, maintenance, operation and support of the boats, launches, and helicopters used in locating and sweeping mines.

The MSC, represented by the *Bluebird* class, is equipped to sweep acoustic, contact, and magnetic mines. It is built of wood, bronze and other non-magnetic materials. The MSO is of similar construction but larger. Most are in the *Agile* class, of the mid-1950's. They have a variable pitch propeller for greater efficiency. The newest MHC is the *Bittern* class . . . a prototype non-magnetic minehunter that can be mass produced.

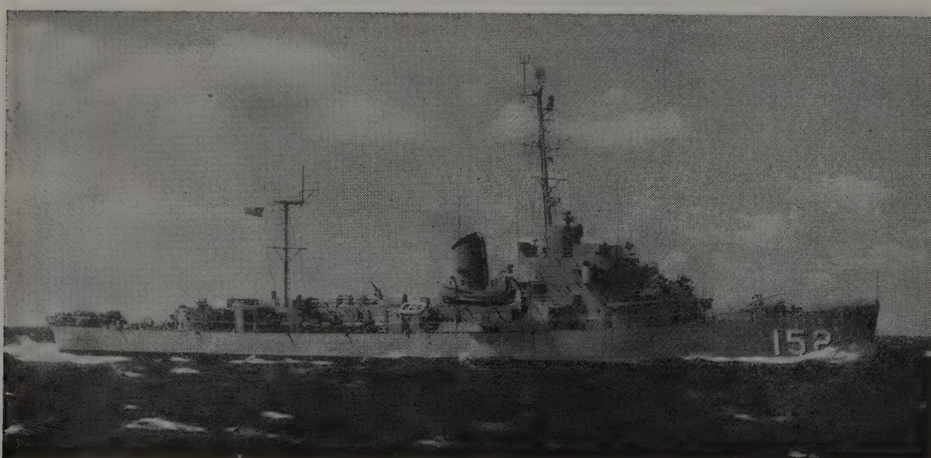


FIG. 1.11 ESCORT SHIP NO. 152—*U.S.S. PETERSON* (DE 152)

1.9. Patrol Ships. These are the DE, DEG, and DER, already mentioned under destroyers. The *High Point* (PCH 1) is the Navy's first operational hydrofoil vessel. This 115-foot subchaser can travel like any other ship, or can "fly" on her submerged foils with her hull clear of the water.

The motor gunboats (PGM) of the 1963–64 shipbuilding programs are also new. Made of aluminum and powered by a combined diesel and gas turbine engine, they do about 40 knots. The PTF, placed in service in 1962–63, are larger and faster than wartime PT boats.

1.10. Command Ships. The first command ship was the *Northampton,* a converted cruiser commissioned in 1953. A much different type is represented by the *Wright,* commissioned in 1963, after conversion from a wartime carrier. She is equipped as a mobile command post for top echelon commands and staffs, and has the most extensive communications facilities ever put aboard ship.

Auxiliary Ships

1.11. Underway Replenishment Ships. These ships enable task forces to operate at sea for extended periods. The record of the Sixth Fleet in the Mediterranean and the Seventh Fleet in the Far East show how independent our Navy can be of shore bases. Newest of the replenishment ships are the

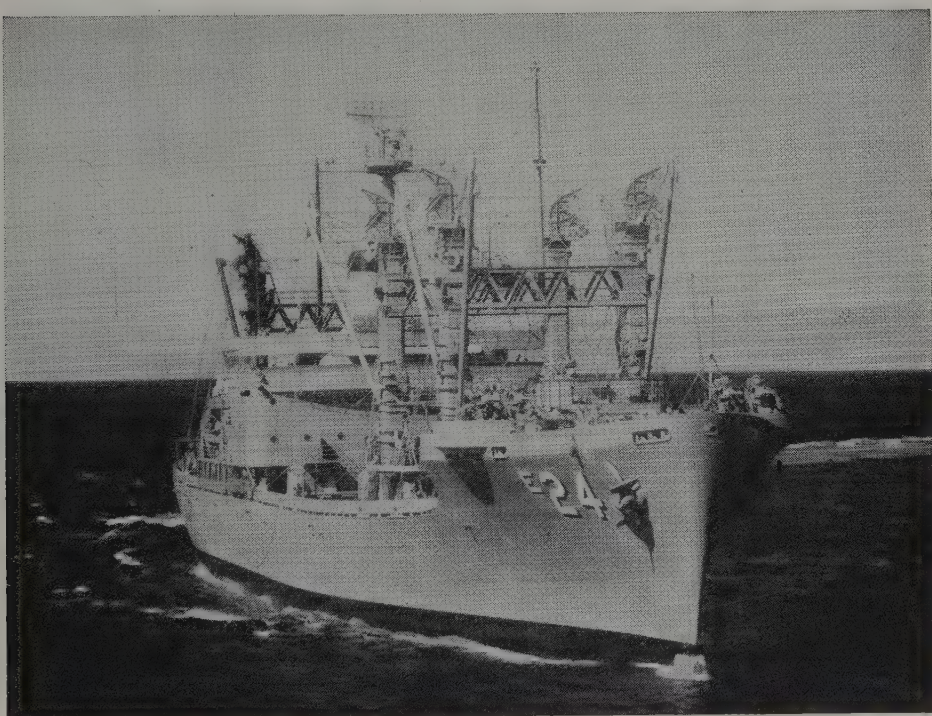


FIG. 1.12 *U.S.S. PYRO* (AE 24)—AMMUNITION SHIP

AFS and AOE. The former, represented by the *Mars* and *Sylvania,* replace more specialized ships such as provisions and stores ships (AF, AKS) in carrying fresh food, aviation supplies, and general stores items. In addition to having the latest gear for side-by-side replenishment, they can use cargo helicopters for vertical replenishment of ships spread out over a wide area.

The *Sacramento,* the first AOE, has capabilities formerly shared by oilers (AO) and ammunition ships (AE). She can carry fuel oil, aviation fuel, diesel fuel—and ammunition, missiles and general provisions. The ammunition ships (AE) fall into three classes, newest of which is the *Suribachi* . . . equipped with an advanced mechanical handling system for loading and transferring ammunition and missiles.

Oilers (AO) are the most numerous of the large auxiliaries. They replenish underway combatant ships with petroleum products. Some have been modernized to supply other ships with ammunition and refrigerated and dry provisions on a limited basis.

1.12. Repair Ships and Tenders. These have the same general mission—performing repair, maintenance, and personnel services for ships unable to do the work for themselves. Their facilities may range from dentists offices

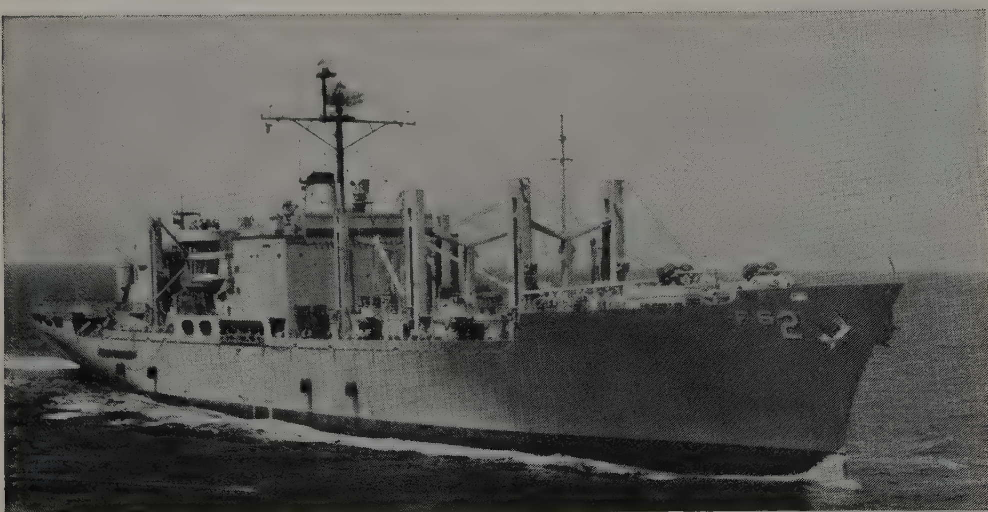


FIG. 1.13 *U.S.S. SYLVANIA* (AFS 2)—COMBAT STORE SHIP

to foundries. Most of the active AD are in the *Arcadia* and *Dixie* classes, dating back to pre-World War II. The newest class is the *Samuel Gompers* (AD 37), which services nuclear-powered ships.

Most submarine tenders (AS) are *Fulton* class ships, built in wartime and modernized for work on nuclear subs. Three tenders designed to support FBM submarines are also in service.

1.13. Other Auxiliaries. The remaining auxiliary ships perform a wide range of services. Their names give a good idea of their duties. Among the larger types are AGB, AGMR, AGR, AGS, and AGTR.

The newest ice breaker (AGB) is the *Glacier*. With her heavily armored bow and rounded forefoot, she can be driven upon the ice and then crush it by her weight. The first floating radio station (AGMR), *Annapolis*, was commissioned in 1963. A former carrier, she has had her flight deck modified with antennas and can supply major communications services to any sea area of the world.

AGR are converted Liberty ships commissioned in the late 1950's to help provide oceanic radar coverage. Their conversion included the installation of extensive communications and detection gear. The only large Navy-manned surveying ships (AGS) are the *Tanner* and the *Maury*, former attack cargo ships. They have special position-finding, echo-sounding and chart-making equipment.

Liberty and Victory ships (AGTR) were converted to conduct tests in communications and electronic radiations. Other important auxiliaries are the submarine rescue ship (ASR), salvage ship (ARS), guided missile ship (AVM) —used to test new missiles; and the true workhorse of the Navy, the fleet ocean tug (ATF).

The Bureau of Ships, in cooperation with the National Aeronautics and Space Administration (NASA) and the Air Force, has awarded contracts for conversion of three World War II *Mission* class tankers for Project APOLLO, NASA's manned lunar flight program.

The existing midbodies of the tankers will be removed and replaced with longer and wider sections. They will house some 108 technicians, along with radar tracking systems, precision navigation equipment, telemetry, and command control and communications facilities. The extensive electronics will supplement land-based instrumentation complexes during the insertion and injection phases of the preparatory unmanned launches and the manned flights.

These ships will be suitable as general purpose instrumentation ships to support other Department of Defense and NASA missile and space programs. They will be operated by the Military Sea Transportation Service, under the operational control of the Air Force.

TABLE 1.2. AIRCRAFT CARRIER DATA

Type	Class	Completion Dates	Full Load Tonnage	Overall Length	Speed (Kts.)
CVAN	*Enterprise*	1961	86,000	1123′	30 plus
CVA	*Kitty Hawk*	1961–68	78,000	1047′	34
CVA	*Forrestal*	1955–59	76,000	1046′	33–35
CVA	*Midway*	1945–47	62.600	979′	33
CVA	*Hancock*	1944–50	42,000	899′	33
CVS	*Essex*	1942–46	41,900	894′	33

TABLE 1.3. CRUISER AND FRIGATE DATA

Type and Class	Completion/ Conversion Dates	Full Load Tonnage	Overall Length	Principal Weapons
CGN—*Long Beach*	1961	16,250	721′	*Talos*, *Terrier*, *Asroc*, 5″ guns
CG—*Albany*	CG: 1962–64 CA: 1945–46	17,800	674′	*Talos*, *Tartar*, *Asroc*, ASW helicopters
CAG—*Boston*	CAG: 1955–56 CA: 1943	17,000	674′	*Terrier*, 8, 5 & 3″ guns
CLG—*Galveston*	CLG: 1958–60 CL: 1944–46	14,600	610′	*Talos*, 6 & 5″ guns, torpedoes
CA—*Newport News*	1948–49	21,500	717′	8, 5 & 3″ guns
DLGN—*Bainbridge*	1962	8,700	564′	*Terrier*, *Asroc*, torpedoes, 3″ guns
DLG—*Belknap*	1964–67	7,900	547′	*Terrier*, *Asroc*, *Dash*, 5 & 3″ guns
DLG—*Farragut*	1959–61	5,350	513′	*Terrier*, *Asroc*, torpedoes, 5 & 3″ guns
DL—*Mitscher*	1953–54	4,730	493′	*Dash*, torpedoes, 5 & 3″ guns

TABLE 1.4. DESTROYER AND ESCORT SHIP DATA

Type and Class	Completion/ Conversion Dates	Full Load Tonnage	Overall Length	Principal Weapons
DDG—*C. F. Adams*	1960–64	4,500	432′	*Tartar, Asroc,* 5″ guns, torpedoes
DD—*Forrest Sherman*	1955–59	3,950	419′	5 & 3″ guns, torpedoes, hedgehogs
DD—*A. M. Sumner*	1944–45 * FRAM: 1960	3,300	376′	5″ guns, *Dash,* torpedoes, hedgehogs
DD—*Fletcher*	1942–44 * FRAM: 1960	2,940	376′	*Dash,* 5″ guns, torpedoes
DDR—*Gearing*	DDR: 1949–53 DD: 1944–46	3,550	390′	Radar, 5″ guns, torpedoes, hedgehogs
DEG—*Brooke*	1962–66	3,430	414′	*Tartar,* 5″ guns, *Asroc, Dash,* torpedoes
DE—*Garcia*	1961–65	3,400	414′	5″ guns, *Asroc, Dash,* torpedoes
DE—*Claude Jones*	1959–60	1,750	312′	3″ guns, hedgehogs, depth charges
DE—*Bronstein*	1960–63	2,650	371′	3″ guns, *Asroc, Dash,* torpedoes
DE—*Evans*	1954–57	1,900	314′	3″ guns, Weapon Alfa, torpedoes, depth charges
DER—*Edsall*	DER: 1951–58 DE: 1942–43	1,850	306′	Radar, 3″ guns, torpedoes, hedgehogs

* Fleet Rehabilitation and Modernization program

Table 1.5. Amphibious Ship Data

Type and Class	Completion/ Conversion Dates	Full Load Tonnage	Overall Length	Principal Features
LPH—*Iwo Jima*	1961–65	18,340	592′	Carries 24 copters, 2100 troops
LPD—*Raleigh*	1962–	14,300	522′	Carries 6 copters, 10 landing craft, 900 troops
LSD—*Thomaston*	Late 1950s	12,150	510′	Carries 21 mechanized landing craft
AGC—*Mt. McKinley*	1944–45	15,295	459′	Command and communications ship
APA—*Paul Revere*	1958–61 (Converted)	18,000	563′	Carries 1500 troops
AKA—*Tulare*	1956	18,000	564′	Carries 575 troops, 27 landing craft, 300 vehicles
LST—*DeSoto County*	Late 1950s	7,100	445′	Carries 700 troops, 20 amphib. vehicles

Table 1.6. Underway Replenishment Ships

Type and Class	Completion/ Conversion Dates	Full Load Tonnage	Principal Features
AFS—*Mars*	1964	16,100	Combines functions of AF, AK, AVS
AOE—*Sacramento*	1964	53,000	Carries 177,000 barrels of oil, plus missiles, ammunition, dry cargo, frozen food
AE—*Suribachi*	1956–59	17,500	Automatic systems for handling and transfer of ammunition and missiles
AF—*Rigel*	1955	15,540	Has 360,000 cu. ft. of refrigerated space
AKS—*Altair*	AKS: 1952–59 AK: 1944	15,580	Carries technical and general stores
AO—*Neosho*	Mid-1950s	38,000	Carries 180,000 barrels of oil
AO—*Cimarron* (Jumbo)	1965–	34,600	Carries 150,000 barrels of oil, plus some ammunition, refrigerated and dry stores
AO—*Cimarron* (old)	1939–45	25,425	Carries 100,000 barrels of oil

Merchant Ships

Merchant ships fall into these broad categories: passenger ships, freighters, tankers, dry bulk carriers, coastal and harbor craft. By methods of propulsion, they are either *steamships* or *motorships.* More specifically and in the order of their development, these methods are: steam reciprocating, steam turbine (low or high pressure), diesel, turbo-electric, diesel electric, gas turbine, turbo-charged diesel, and nuclear-powered (using a nuclear reaction for heat source).

1.14. Recent Advances. Modern ships are built to take the rigors of wind and wave—and even, as with the nuclear-powered *Savannah,* the "maximum credible incident" in a collision or grounding. While the term "unsinkable" went out when the *SS Titanic* went down, new techniques of ship construction and improved materials have contributed greatly to ship safety. Effective compartmentation has been augmented by the installation of such devices as those allowing watertight doors to be quickly shut by means of a switch on the bridge.

Advances in cargo ships since World War II include greater payloads and higher speeds—and increased automation (or mechanization) through the use of labor-saving devices. This in turn, allows for reduction in crew sizes, both on deck and in the engineering spaces. *Containerization,* another advance, enables *vans* and *cargotainers* up to the size of over-the-road semi-trailers to be lifted at pierside from a truck chassis and then stowed in special brackets on the ship's deck or to be lowered into specially constructed holds in a *containership.*

In tankers the greatest advances in size have been made. A tanker of 20,000 dead-weight tons (DWT) was considered large during World War II, there are now giant tankers up to 150,000 DWT.

1.15. Passenger Ships. In contrast to tankers, passenger ships have tended to decrease in size—except for a handful of North Atlantic liners built to uphold national prestige.

Rather stylized in their designs for a few decades, passenger ships now have a much greater diversity in design and tend to be far sleeker and racier-looking. The 820-foot *Canberra* (British built, 1961), for example, has her single mast and twin in-tandem stacks placed well aft. The 748-foot *Rotterdam* (Dutch built, 1959) has in-tandem stacks aft but a low, rakish, full-bodied mast forward.

In 1962 France launched the *France:* 1035 feet long. In other particulars, Britain's *Queen Elizabeth* is conceded to be the biggest, even though about four feet shorter (overall length) than the *France;* for she measures 83,673 gross tons to the *France*'s 66,348. The *United States,* however, holds the records for both east and westbound North Atlantic passages, with speeds in excess of 35 knots. Italy has built the most passenger liners in recent years, followed by Great Britain, Holland, France, Sweden, Greece, Germany,

FIG. 1.14 *S.S. BRASIL*, PASSENGER SHIP. *Courtesy Moore-McCormack Lines*

FIG. 1.15 ONE OF THE LARGER PASSENGER LINERS, *S.S. INDEPENDENCE*

FIG. 1.16 TUGS PROVIDE ESCORT FOR *S.S. SANTA ROSA*, PASSENGER SHIP. *Courtesy Moran Towing & Transportation Co., Inc.*

and Israel. Russia entered the field about 1960. The resurgent Japanese have not sought to regain their pre-war eminence in trans-Pacific passenger travel.

Since 1950, U.S. yards have built six liners: *Brazil* and *Argentina,* modernistic in appearance, for the Buenos Aires run; *Santa Rosa* and *Santa Paula* for Caribbean cruising; and the splendid *Independence* and *Constitution* for the Mediterranean. Three Mariners, of the 35 built as the world's largest and fastest freighters of their time, have been converted for passenger use. Cargo-passenger liners (or "combos") are smaller than the famous passenger liners and depend mainly upon cargo for income. Their sizes range as greatly as their routes.

1.16. Cargo Ships. Far more numerous than the foregoing are the cargo liners, or scheduled freighters. They may carry up to 12 passengers without signing on a ship's doctor, additional radio officers, and other personnel. U.S.-flag cargo liners now emphasize speed, ever since the Mariners first proved their worth in the 1950's. More voyages per year enable U.S. cargo liners to compete against lower foreign building and operating costs. The 15 Government-subsidized lines are, in their replacement programs, developing improved Mariners—such as the *Searacer, Challenger,* and *Constellation* classes.

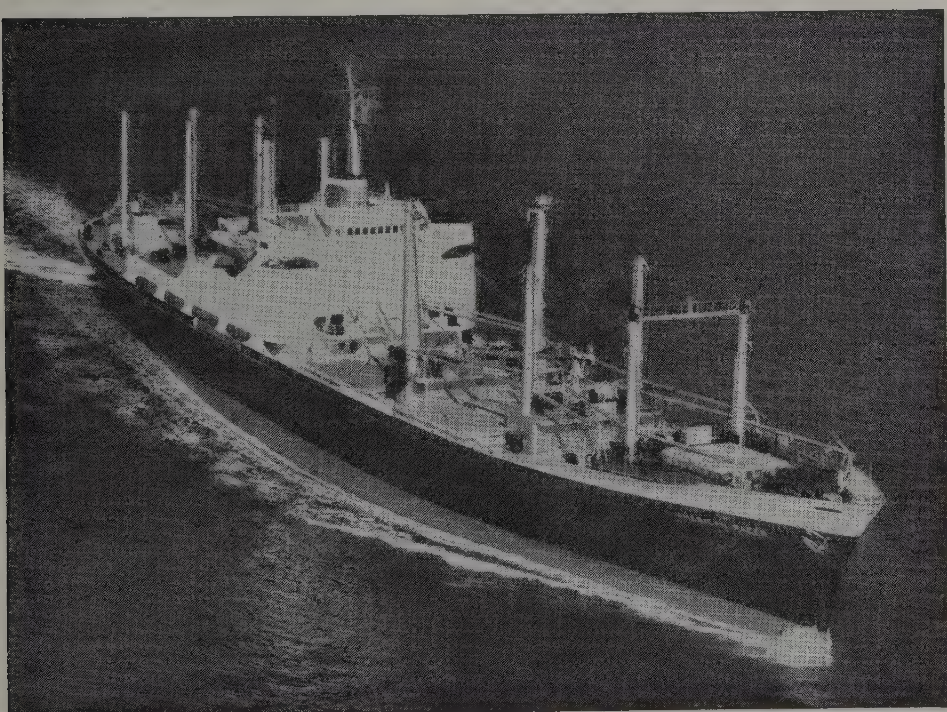


FIG. 1.17 *S.S. AMERICAN RACER,* MODERN CARGO SHIP. *Courtesy Moran Towing & Transportation Co., Inc.*

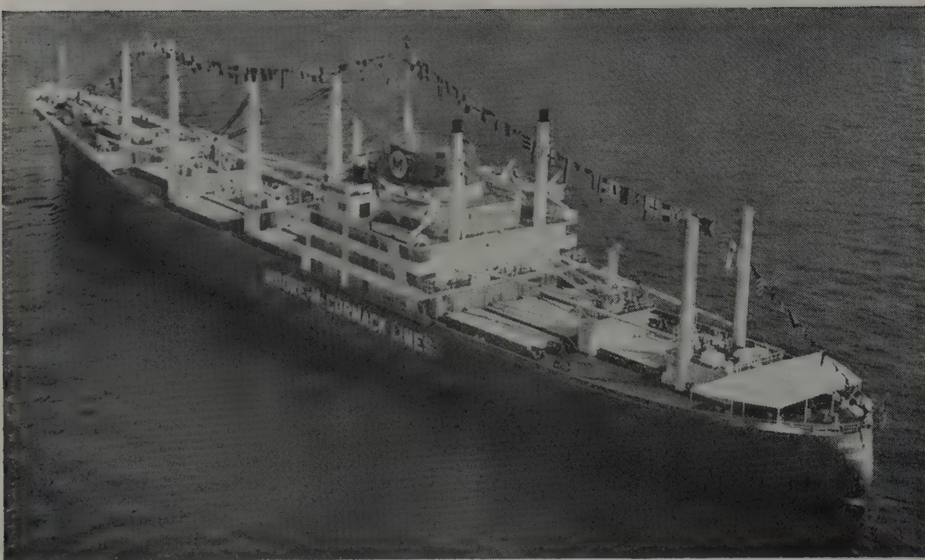


FIG. 1.18 S.S. MORMACARGO—HIGHLY AUTOMATED CARGO LINER. *Courtesy Moore-McCormack Lines*

FIG. 1.19 A REFRIGERATED CARGO SHIP, S.S. LIMON. *Courtesy Moran Towing & Transportation Co., Inc.*

In the late 1940's, a large American tramp fleet carried relief cargos to war-torn Europe and Asia. Wartime Liberty and Victory ships formed the backbone of this operation—and of the free world's cargo fleets, until the late 1950's. Now these ships are exchanged or scrapped in favor of long-range Maritime Commission types being withdrawn from the National Defense Reserve Fleet.

"Tramps" differ from cargo liners mainly in the vagrant nature of their employment. The latter sail on regular schedule; U.S.-flag cargo liners must serve an approved essential foreign trade route to qualify for a differential subsidy by the Government.

The "cross-traders" are freighters, usually Scandinavian, who sail distant seas but seldom, if ever, see their native land. The crews fly home every third or fourth year for a number of months' paid vacation.

1.17. Tankers. At one time new tankships carried refined petroleum products, and older ships carried asphalt or molasses. Now they haul many liquids in bulk: dangerous molten sulphur, liquefied petroleum gases, methane and propane at 258 degrees F., wine, orange juice—even beer, liquid latex, palm oil, and, on occasion, grain in bulk. The chemical tanker with its assortment of alcohol, acids and solvents, is becoming more common. However, the standard tanker remains that ship that hauls POL (petroleum, oil lubricants) products. While some tankers have been built with machinery amidships, the conventional tanker silhouette is: machinery and most of the quarters aft; high catwalks connecting the three "islands" formed by the raised forecastle, midship house, poop; ullage caps over all tank openings; an array of pump lines and valves over the tank tops (forming the main deck) and under the catwalks. Though large tankers without catwalks or midship bridge structures are far from common, a few have been built this decade—huge vessels up to 750 feet in length, and with a completely open expanse of

TABLE 1.7. SOME AMERICAN MERCHANT SHIP TYPES

Ship	Tonnage *	Speed (knots)	Passenger Capacity	Crew
United States	53,000 gross	35	2,000	1,000
Brasil/Argentina	15,257 gross	23	557	400
Independence/Constitution	30,000 gross	22.5	1,068	650
American Racer	13,000 DWT	21	4	37
Mormacvega/Mormaclynx	12,100 DWT	24	12	35
Savannah	9,656 DWT	21	0	70
Export Agent/Export Aide	11,000 DWT	18.5	12	54
Manhattan (tanker)	108,590 DWT	19	0	60

* Gross tonnage is the internal capacity of a ship expressed in "tons" of 100 cubic feet of "permanently enclosed space" as defined by highly complex rules in process of change for more than a century. Deadweight is the carrying capacity of a ship in long tons of 2240 pounds. To illustrate: When a freighter is converted to a passenger ship (without change in length, beam or depth) her DWT decreases, roughly as her gross tonnage increases.

deck from bow to high afterhouse. This design is also being applied to giant ore carriers.

THE MILITARY SEA TRANSPORTATION SERVICE

1.18. MSTS Ships. Often called "the world's largest shipping line," the Navy's Military Sea Transportation Service is a fleet of more than 125 ships. In addition MSTS provides more than $1,000,000 a day to other U.S. (merchant) ships hauling defense cargo and fuel under contract. With the status of a fleet within the Navy, MSTS operates a varied assortment of transports,

FIG. 1.20 AN ICE-STRENGTHENED MSTS GASOLINE TANKER—*USNS ALATNA* (T-AOG 81)

FIG. 1.21 *USNS GEN. W. H. GORDON* (T-AP 117), MSTS TRANSPORT. U.S. *Army Photograph*

tankers, freighters, arcticized ships, and scientific research-and-support ships. MSTS ships are of three principal types: transports, cargo ships (freighters), and tankers. Transports are of two main types: the 622-foot "P2-S2-R2"—17,806 gross tons, up to 2240 passengers (peacetime); and the 609-foot "P2-SE2-R1"—16,039 gross tons, up to 1707 passengers (peacetime). These sail between New York and Bremerhaven and between San Francisco and the Far East, carrying both troops and military dependents.

Cargo ships are, in the main, of the wartime Victory ship design: 10,600 DWT, 455 feet in length, 16½ knots, crew of 50—and working worldwide MSTS schedules. The *Brostron* and *Marine Fiddler* deserve special mention. These are 13,400-ton "C-4s" rated as *heavy lift ships*, being capable of 150-ton lifts with their massive booms and cargo rigs. Former wartime "jeep carriers" now serve as *aircraft ferries*. They carry both fixed wing aircraft and helicopters where required by defense needs.

Tankers are of two main types, both fixtures of the merchant service. The "T-2" mass produced during World War II, is a 524-footer with turbo-electric drive and having a capacity of 140,000 barrels. The newer "T-5" has steam-turbine drive, is 620 feet in length, and has a 190,000-barrel capacity.

One cargo ship type in which MSTS has pioneered (with the *USNS Comet*) is the roll on/roll off ship, in which cargo-loaded vehicles are driven aboard the ship and parked in the hold—instead of the cargo being cargo-boomed-and-whipped aboard. At the other end of the voyage, the vehicles are merely driven off the ship. Other ships of this type are being built both for the Navy and for commercial companies.

Certain small tankers and cargo ships have been winterized—mainly in the matter of hull reinforcement—for work in ice areas.

The scientific-support and special-purpose ships of MSTS have the greatest diversity. Termed *special project ships*, they carry out a wide variety of duties. They support scientific endeavors in oceanographic surveys, hydrographic research, geodetic surveys, undewater acoustic research, missile telemetry and recovery, and long-distance communications.

Seven converted Victory ships and two ex-C-4 troopships (plus eight other types) carry out missile tracking, instrumentation, and recovery functions. Three other ex-Victories engage in world-wide ocean surveys; another is the world's first satellite communications ship. Other ex-Victories are one-stop supply ships, supporting the overseas-based submarine tenders that, in turn, support the ballistic missile submarines. Smaller in size than the Victories are the oceanographic research ships (AGOR). These 205-footers—and there is a growing fleet of them—are, for all purposes, floating scientific laboratories.

2

Ship Construction

The Hull

The main body of a ship exclusive of masts, superstructure, etc., is called the *hull.* For a steel ship it is made up of plates covering a framework which in many ways is similar to the framework of a building. The hulls of various types and classes of vessels are basically similar, with certain modifications to suit the mission of the vessel.

A very important part of the frame of any vessel is the bottom centerline longitudinal, known as the centerline keelson. This assembly is generally made up of vertical and horizontal members, the vertical member being called the centerline keel, the bottom horizontal member, the flat-keel, and the upper horizontal member, usually lesser width than the flat keel, being known as the keel Ryder plate. These three members form a deep girder type of structure of longitudinal continuity and strength which will withstand the various severe loadings to which the ship is subject, as when the ship is drydocked or inadvertently grounded. This girder is often referred to as the backbone of the ship. All parts of the keelson are continuous from the forward end, where it joins the stem, to the after end, where it joins the stern post, or stern-post assembly if the stern post does not exist.

Radiating from the keel are a series of frames which give the hull its shape and act as supports for the shell plating, decks, etc. The frames, together with the longitudinals constitute a framing system. The framing system is said to be longitudinal if the fore-and-aft members are continuous. Transverse framing system is generally used in modern merchant-ship construction. Naval surface vessels use a longitudinal framing system.

Prior to the development of welding techniques, all portions of the ship's structure were joined by riveting. This practice has given way almost entirely to welding. There is a saving in weight of as much as 10 to 15 percent when welding is used. In addition, it is faster, cheaper, and gives a smoother surface that is better able to resist corrosion and to reduce skin friction in the underwater body of a ship. The use of welded construction does, however, call for a very carefully controlled assembly sequence in order to minimize locked-in stresses. Specifications for larger vessels sometimes call for a combination of welded and riveted construction. The riveted joints are located at the gunwale and bilge stroke to act as crack arrestors.

Larger ships are usually fitted with inner bottoms which extend up the side of the ship to or above the water line. Large combatant vessels were often fitted with heavy armor plate surrounding the machinery spaces and other vital spaces from slightly above the water line to several feet below the water line.

The ship is further subdivided into as many small compartments as is practical, consistent with the mission of the vessel, in order to minimize leakage and flooding if the outer shell is damaged.

Bulkheads are used to subdivide the ship's interior vertically into watertight compartments for the preservation of buoyancy and stability. Oiltight bulkheads are fitted to form the necessary fuel oil tanks, and nonwatertight bulkheads are fitted to provide stowage and living spaces where watertightness is not essential.

2.1. Hull Shapes. The power characteristics, such as speed, of a ship depend to a great extent on the shape of her hull below the water line, i.e., the under-water body. The widest part of the hull is near the halfway point between the bow and stern, and the hull in this vicinity is called the middle-body section. The bottom and sides in the midship section are joined by a curve which completes an approximate right angle and which is called the turn of the bilge. From the middle-body section the lines of the hull slope smoothly to the bow and stern in what may become a hollow or reverse curve at some point before reaching them. The narrowing part of the under-water body forward of the middle-body section is called the entrance. The corresponding part aft is called the run. A ship that has a long and tapering entrance and run and a proportionally short middle-body section is said to have fine lines. A fast man-of-war generally has fine lines. A slow cargo carrier has not. Her boxlike middle-body section is comparatively long to give her greater carrying capacity.

If the sides slope outward from near the turn of the bilge toward deck level, they are said to be flared. If they slope inward, the amount of the slope is called the tumblehome. If a deck slopes from the centerline to the side, it is said to be cambered.

There are as many refinements on this general scheme of the underwater body as there are ship designs and special uses for ships. Generally the run is somewhat longer than the entrance, and the after part of the run is narrowed for a greater distance to allow for the installation of rudder and propellers. The keel may be shortened aft, and the stern post may slant from the end of the keel to the water line for the same reasons. These characteristics are known as reduced after deadwood. Cutting away the after deadwood has an important effect on ship handling, which will be discussed in a later chapter. The lines of some ships, instead of coming to a sharp edge at the bottom of the stem, expand at that point into a rounded shape of comparatively small diameter extending from the keel to a few feet below the water line. This shape is known as a bulbous bow and enables a vessel so fitted to attain greater speeds at or near full power than a vessel not so equipped. (The stem at and a few feet on each

side of the water line is a sharp edge.) In addition, bulbous bows can be used as oceanographic observation spacers or as fairings for sonar.

The shape of a ship's underbody explains the great difference between shipbuilding and ordinary construction. Each frame member must be fitted to the desired contour of the hull, and side plates must be bent to the proper shape before being fastened to the frames in order that the completed ship may have her designed characteristics.

2.2. Submarine Hulls. The hull of the submarine sets her apart from other ships. The entire submarine may be considered a complete hull. Actually, there are three major hull elements. The basic element is the pressure hull which

FIG. 2.1 SKETCH OF A POLARIS SUBMARINE FIRING ONE OF ITS MISSILES

contains most of the vessel's vitals—engines, living and working spaces, etc. The pressure hull is basically cylindrical, though part of the hull is conical. Mounted on the pressure hull is the superstructure, and fairwater, which may contain a conning tower. The conning tower only is watertight and contains additional vital spaces and equipment. Mounted around the pressure hull are ballast and fuel tanks. These are *exterior* to the pressure hull. The three elements are smoothly combined to give the submarine its distinctive hull shape. Figure 2.1 shows these features in the artist's conception of the hull of one of the newer missile submarines.

2.3. Decks. Decks are used primarily to provide structural strength, shelter, working spaces, and living quarters; and secondarily to subdivide the hull horizontally into greater number of watertight compartments. For transversely framed ships the decks are supported by fore-and-aft members called deck girders, and by athwartship members called deck beams. Deck beams are in turn supported by stanchions which provide the decks with support additional to that afforded by the bulkheads. For longitudinally framed ships the decks are supported on longitudinal members that in turn are supported by transverse bulkheads and by athwartship girders. These girders extend between web frames on the side shell and have intermediate stanchion support. The highest deck extending from stem to stern is called the main deck. A partial deck above the main deck at the bow is called the forecastle deck; at the stern, poop deck; amidships, upper deck. The name upper deck, instead of forecastle deck, is applied to a partial deck extending from the waist to either bow or stern. A partial deck above the main, upper, forecastle, or poop deck and not extending to the side of the ship is called a superstructure deck. A complete deck below the main deck is called the second deck. Two or more complete decks below the main deck are called the second deck, third deck, fourth deck, etc. A partial deck above the lowest complete deck and below the main deck is called a half deck. A partial deck below the lowest complete deck is called a platform deck. Where there are two or more partial decks below the lowest complete deck, the one immediately below the lowest complete deck is called the first platform, the next is called the second platform, etc. Decks which for protective purposes are fitted with plating of extra strength and thickness are further defined for technical purposes as *protective* and *splinter* in addition to their regular names.

2.4. Fittings. Fittings are various structures and appliances attached to the hull to assist in handling the ship or performing the ship's work, to provide for the safety and comfort of the crew, or merely for ornamental purposes (see Fig. 2.2). They may be affixed solidly to the hull or may be capable of a limited amount of motion. They may be operated by hand or by power. They may be found in any part of the ship, including the underwater body, although the commonest and most useful fittings are generally encountered around the weather decks.

Chocks are some of the most numerous and useful fittings found aboard ship. They generally take the form of castings or forgings bolted or riveted to the hull near the side along weather decks and are used for the purpose of guiding lines led aboard. The most common form is the open chock that has an opening on top through which the line is dropped and two curved parts called horns to hold it in. If the horns meet and the line must be led through the opening, it is called a closed chock. The heavy closed chock built at the extreme bow of destroyers and other light vessels for guiding a towline is commonly known as the bull nose. The inner surfaces of chocks are smoothed and rounded to

avoid chafing the lines. Some have rollers fitted on each side for the same purpose, in which case they are known as roller chocks.

Bitts are usually found in the neighborhood of chocks and somewhat inboard of them. They are heavy vertical cylinders, usually cast in pairs and often used

FIG. 2.2 FITTINGS ON A MISSILE SHIP. *Official U.S. Navy Photograph*

for making fast lines that have been led through the chocks. The upper end of a bitt is larger than the lower end or is fitted with a lip to keep lines from slipping off accidentally. As bitts are often required to take very heavy loads, extra frames are worked into their foundations to distribute the strain. Bitts are sometimes built and installed ruggedly enough so that the ship may tow or be towed by them. When built in pairs, each bitt is sometimes called a horn.

Another common fitting is the davit. Davits are set in sockets which allow them to rotate. They are made of heavy pipe or plates and are angled so that

the upper end or head of the davit will plumb some space below it at a distance from the davit's base. A tackle is rigged at the davit head so that weights can be lifted and swung as the davit is rotated. The most common use for davits is to carry lifeboats, but they are sometimes rigged to lift or lower weights over the side or out of trunks and holds.

There are numerous smaller but very useful fittings found about the weather decks. A plate with an eye attached, riveted to the deck to distribute the strain over a large area and to which a block can be hooked or shackled, is called a pad or padeye. An eyebolt serves the same purpose and may be attached to the deck or to a bulkhead or a frame overhead. If the eyebolt carries a permanent ring, it is called a ringbolt. Cleats are light, double-ended fittings on which lines are made fast. Awning stanchions and lifeline stanchions are found at the ship's side on weather decks and are used to rig awnings and lifelines. Some of these are either hinged or set in sockets so that they can be cleared away when this is necessary. Sockets are often set in the deck for special purposes, such as setting the king post for a boom and topping-lift. Deadlights are heavy glass plates set in upper decks, and ports are fixed or hinged heavy glass plates set in the ship's side.

Winches and cranes are the most common and most useful power fittings found aboard ship. A winch consists of a heavy frame fastened solidly to the deck and an engine or motor that turns a horizontal shaft mounted in the frame, usually with a drum fastened to each end of the shaft. If the line is revolved around the drum for several turns and is tended carefully, it will withstand a heavy strain and can be accurately controlled. Blocks rigged to padeyes or eyebolts are commonly used to give lines a fair lead to the winch drums. In case a line has a limited and repeated travel, as when cargo is being handled in and out of a hold, and for heavy loads, the line is attached permanently to a winch drum and handled by winding and unwinding it on the drum according to the direction of the shaft's rotation. Winches take the place of an enormous amount of manpower and are invaluable in speeding up operations even when sufficient manpower is available. A winch that is used primarily to handle the anchor cables, but usually having horizontal drums or a vertical capstan in addition, is called an anchor windlass.

Cranes may be regarded as large, power-driven davits. A crane may be built up as a solid structure or rigged with a boom that can be raised and lowered so as to plumb different distances from its base. The hauling part of a permanently rigged wire rope tackle for lifting weights is made fast to a drum. Motors or engines lift or lower weights by rotating the drum, rotate the crane, and lift or lower the boom. The crane is used primarily for hoisting and lowering heavy weights, such as boats and airplanes, over the side, but it can be used for many other purposes within its radius, such as for heavy vertical lifts and rotation.

The location of fittings and other fixed objects on deck is normally identified by the numbers of the closest ship's frame. Certain frames, usually every fifth

one, have their numbers cut or stamped in an accessible location near each side of the ship. Intermediate frames can be located by measuring from a marked frame in multiples of the frame spacing or the distance between frames, which is usually uniform. The number of frames in the hull and the length of the frame spacing are useful knowledge to have about any ship.

2.5. Compartment Designation for Warships. Every space in a warship (except for minor spaces, such as peacoat lockers, linen lockers, and cleaning gear lockers) is considered as a compartment and assigned an identifying letter-number symbol. This symbol is placed on a label plate secured to the door, hatch, or bulkhead of the compartment. There are two systems of numbering

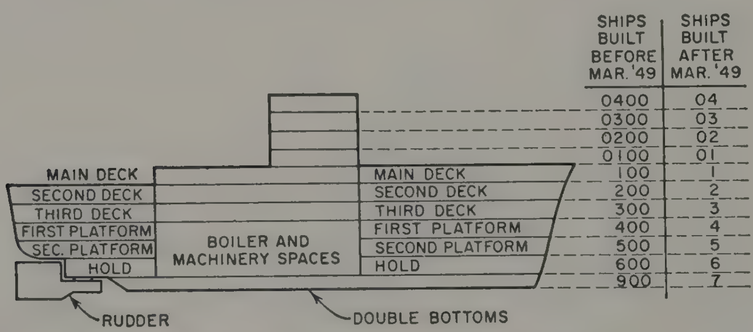


FIG. 2.3 DECK SYMBOLS FOR NAVY SHIPS

compartments, one for ships built prior to March 1949, the other for ships built after March 1949. Both these systems agree, however, in one respect: compartments on the port side have even numbers, those on the starboard side have odd numbers. The two systems resemble each other also in the fact that a zero precedes the deck number for all levels above the main deck. Figure 2.3 shows both systems of numbering decks. The older system uses 100, 200, 300, etc., series and always 900 for the double bottoms, while the new system uses 1, 2, 3, etc., and the double bottoms are given whatever number befalls them. For ships built prior to March 1949, the first letter of the identifying symbol is A, B, or C, and indicates the section of the ship in which the compartment is located. The A section extends from the bow of the ship aft to the forward bulkhead of the engineering spaces. The B section includes the engineering spaces, while the C section extends from the after bulkhead of the engineering spaces aft to the stern.

After the division letter, the deck designation comes next in the symbol. Main deck compartments are indicated by numbers such as 102, 109, 117, etc. Second deck compartments run from 201 through 299, third deck compartments form a 300 series, etc. A zero preceding the number indicates a location above the main deck. The double bottoms always form the 900 series on any ship built before March 1949, regardless of the number of decks above.

What the compartments are used for is indicated by the following letters:

A—Supply and Storage
C—Control
E—Machinery
F—Fuel
L—Living Quarters
M—Ammunition
T—Trunks and Passages
V—Voids
W—Water

Here is an example of a compartment symbol on a ship built before March 1949:

C — 2 1 7 — A

A—Supply compartment
17—Compartment number (starboard side)
2—Second deck
C—After part of ship (C section)

2.6. Ships Built After March 1949. For ships constructed after March 1949, the compartment numbers consist of a deck number, frame number, relation to centerline of ship, and letter showing use of the compartment. These are separated by dashes. The A, B, C divisional system is not used.

Deck Number. Where a compartment extends down to the bottom of the ship, the number assigned to the bottom compartment is used. The deck number becomes the first part of the compartment number.

Frame Number. The frame number at the foremost bulkhead of the enclosing boundary of a compartment is its frame location number. Where these forward boundaries are between frames, the forward frame number is used. Fractional numbers are not used. The frame number becomes the second part of the compartment number.

Relation to the Centerline of the Ship. Compartments located on the centerline carry the number 0. Compartments completely to starboard are given odd numbers, and those completely to port are given even numbers. Where two or more compartments have the same deck and frame number and are entirely starboard or entirely port of the centerline, they have consecutively higher odd or even numbers, as the case may be, numbering from the centerline outboard. In this case, the first compartment outboard of the centerline to starboard is 1; the second, 3; etc. Similarly, the first compartment outboard of the centerline to port is 2; the second, 4; etc. When the centerline of the ship passes through more than one compartment, the compartment having that portion of the forward bulkhead through which the centerline of the ship passes carries the number 0, and the others carry the numbers 01, 02, 03, etc. These numbers indicate the relation to the centerline and are the third part of the compartment number.

Compartment Usage. The fourth and last part of the compartment number is the letter which identifies the primary usage of the compartment. On dry

TABLE 2.1. COMPARTMENT LETTERS FOR SHIPS BUILT AFTER MARCH 1949

Letter	Type of Compartment	Examples
A	Stowage spaces	Storerooms; issue rooms; refrigerated compartments.
AA	Cargo holds	Cargo holds and cargo refrigerated compartments.
C	Control centers for ship and weapon-control operations (normally manned)	CIC room; plotting rooms; communication centers; radio, radar, and sonar operating spaces; pilothouse.
E	Engineering control centers (normally manned)	Main propulsion spaces; boiler rooms; evaporator rooms; steering gear rooms; auxiliary machinery spaces; pump-rooms; generator rooms; switchboard rooms; windlass rooms.
F	Oil stowage compartments (for use by ship)	Fuel-oil, diesel-oil, and lubricating oil compartments.
FF	Oil stowage compartments (cargo)	Compartments carrying various types of oil as cargo.
G	Gasoline stowage compartments (use by ship)	Gasoline tanks, cofferdams, trunks, and pumprooms.
GG	Gasoline stowage compartments (cargo)	Gasoline compartments for carrying gasoline as cargo.
K	Chemicals and dangerous materials (other than oil and gasoline)	Chemicals, semi-safe materials, and dangerous materials carried for ship's use or as cargo.
L	Living spaces	Berthing and messing spaces; staterooms, sanitary spaces, brigs; medical spaces; and passageways.
M	Ammunition space	Magazines; ammunition and missile handling rooms; ready service rooms; clipping rooms.
Q	Miscellaneous spaces not covered by other letters	Shops; offices; laundry; galley; pantries, unmanned engineering, electrical, and electronic spaces.
T	Vertical access trunks	Escape trunks or tubes.
V	Void compartments	Cofferdam compartments (other than gasoline); void wing compartments.
W	Water compartments	Drainage tanks; fresh-water tanks; peak tanks; reserve feed tanks.

and liquid cargo ships a double-letter identification is used to designate compartments assigned to cargo carrying. The letters are shown in Table 2.1.

The following example of a compartment number illustrates the application of these principles of compartmentation for ships built after March 1949:

3 — 7 5 — 4 — M

M — Ammunition compartment

4 — Second compartment outboard of the centerline to port

75 — Forward boundary is on or immediately aft of frame 75

3 — Third deck

Hull Systems

Piping built into the hull which carries a liquid or a gas is known as a hull system. The principal hull systems are:

Firemain	Fresh water
Sprinkling	Drainage
Flushing	Compressed air
Damage Control Flooding	Fuel-oil
Ballasting	Aircraft fuel

2.7. Firemain System. The firemain system in large ships forms a loop throughout the greater portion of the ship. Cross-connections are installed between mains in most main transverse watertight subdivisions. The loop may be arranged in a horizontal or vertical plane. In aircraft carriers, a bypass main is installed below the uppermost service mains, thus incorporating the features of both the horizontal and vertical loop.

In small ships, such as destroyer escort types, a single main is provided on the damage control deck.

In combatant ships, the firemain can be segregated into smaller independent sections so as to minimize loss of pumping capacity in event of localized system damage.

2.8. Sprinkling System. The magazines of a warship are divided into groups, according to location. Each group is supplied by a separate sprinkling system connection leading from the firemain at a convenient location and controlled by a group control valve. The group control valves are operated from remote control stations, hydraulically, or mechanically. Sprinklers may also be actuated automatically by a thermostat when there is a temperature rise in the magazine.

2.9. Flushing System. For sanitary spaces, flushing water at pressures around 30 psi is supplied. Present practice is to provide branches from the firemain, via stop valves and reducing valves, wherever flushing services are required.

2.10. Damage Control Flooding. In aircraft carriers, remote-operated, hydraulically controlled flood valves are installed in counter-floodable voids. The latest practice provides a single flood valve to service several such voids in order to minimize the number of openings in the hull. These valves permit rapid counter-flooding even when power is temporarily lost.

2.11. Ballasting System. It is often necessary to ballast fuel oil stowage tanks with salt water after the fuel oil is burned, in order to maintain proper list, trim, draft, torpedo protection, and stability. Fuel oil ballast tanks in such ships are flooded with salt water from the sea or from the firemain through a manifold. Removal of ballast water from the tanks is accomplished

by eductors actuated from the firemain. Fuel oil service tanks should never be ballasted with water.

2.12. Fresh-Water System. Fresh or "drinkable" water, called potable water, is usually stored aboard ship in special tanks, low in the ship. From these tanks, it is delivered to necessary outlets, such as scuttlebutts, lavatories, galley sinks, and the like, through the fresh-water system. This consists of a pump and pressure tank or continuously operating centrifugal pumps, which maintain pressure in the system. Pumps are usually located near the fresh-water tanks, and frequently in engineering spaces.

2.13. Drainage System. Each ship has some means provided for removing water from within its hull. Systems of piping, with or without pumping facilities installed for this purpose, are termed *drainage systems.*

Drainage systems are divided, on most ships, as follows:

1. Main drainage system
2. Secondary drainage systems
3. Plumbing and deck drains
4. Weather-deck drains
5. Feed drains in machinery spaces

In addition to the above systems, the following portable pumps are used to drain flooded areas not provided with drainage facilities:

1. Electric submersible pumps
2. "P-250-type" pump
3. Jet pumps (eductors)

The main drainage system runs throughout the main machinery compartments. However, on some ships it extends well into the bow and stern. On smaller ships the main drain consists of a single pipe running fore and aft, usually amidships. On larger ships it is a loop system, extending along both sides of the engineering compartments and joined at the ends. Main drainage systems may be used on many later type ships to drain "floodable" voids used in counter-flooding, after such voids have been flooded, and to empty fuel oil tanks which have been ballasted with sea water. Eductors, actuated from the firemain, are used to provide suction lift.

Secondary drainage systems serve to drain spaces forward and aft of the main machinery compartments. The piping is smaller in size than that used in main drainage systems. It may be a continuation of the main drainage system, but in many instances they are not connected.

Plumbing and deck drains are provided for draining fixtures and compartments within the ship by gravity. Gravity drainage piping is installed most extensively in compartments above the water line. On large ships, some compartments near or below the water line may be drained to compartments lower in the ship, where the water can be pumped overboard. These lower

compartments are bilges and bilge wells, shaft-alley sumps, drain tanks, or sanitary drain tanks.

2.14. Compressed Air System. Ships rely on compressed air for many tasks and services. Examples of tasks include starting of emergency diesel generators, launching torpedoes and operation of valves and controls. Examples of services include operation of pneumatic tools, servicing vehicles and charging of divers tanks.

On the submarine the compressed air system is of major importance. This is because compressed air is used in blowing ballast tanks for maintaining the proper buoyancy. Other uses include the operation of control systems, torpedo ejection and emergency breathing.

Compressed air is provided, normally, by shipboard compressors and stored in receivers or flasks for use as required.

2.15. Fuel-Oil System. The fuel-oil pumping system in large ships consists of a loop serving all fuel-oil tanks and permitting transfer of fuel from storage tanks to service tanks and thence to fuel-oil service pumps. The latter pump the fuel oil to the fuel-oil heaters and thence to the burners in the boilers. Included in the system are topside fuel-oil-filling connections, which lead down to the loop.

This system is used for *transfer* of liquid for correction of list and trim, or improvement of stability or reserve buoyancy after damage, and furnishes a possible avenue for progressive flooding.

2.16. Aircraft Fuel Systems

Aviation gasoline system. Ships carrying or tending piston engine type aircraft store and handle highly volatile aviation gasoline. Gasoline systems are designed to minimize the inherent fire and explosion hazard.

The majority of the gasoline systems installed are of the sea water displacement type. During aircraft fueling operations the gasoline pumped from the storage tanks is displaced with sea water which is supplied either from the fire main through reducing valves or from separate sea water pumps. When receiving gasoline the sea water in the tanks is displaced with the gasoline entering the tanks. This keeps the tanks full, eliminates dangerous pockets of gasoline vapor, and provides a positive suction head to the gasoline pumps.

The gasoline tanks are surrounded by inerted cofferdams. Ships with large gasoline storage capacities, such as aircraft carriers, are provided with a "saddle type" tank arrangement, consisting of an outer tank, an inner tank and a draw-off tank. The outer tank fits over the inner and draw-off tanks as a saddle. The sea water is supplied to the outer tank and the gasoline is drawn off the draw-off tank. The three tanks are interconnected in series by sluice piping. This arrangement provides an additional water layer protection around the gasoline inner and draw-off tanks as soon as the sea water has displaced the gasoline in the outer gasoline tank.

Delivery of gasoline to aircraft fueling stations, such as the hangar and flight deck stations on an aircraft carrier, is accomplished by gasoline pumps, either electric motor or water turbine driven.

Gasoline aircraft service stations are located on one side of the hangar and flight deck areas. The need for gasoline systems will gradually disappear with the replacement of piston engine type aircraft with gas turbine engine type aircraft.

Aviation Gas turbine fuel (JP-5) system. Ships carrying or tending gas turbine engine type aircraft store and handle gas turbine engine type fuel (JP-5). This fuel is a high flash point fuel and is considered safe for storage aboard ships in unprotected tanks similar to ship's diesel oil tanks. The use of a high flash point fuel also allows elimination or reduction in the safety requirements associated with gasoline systems, such as explosion-proof equipment, special firefighting and ventilation requirements. However, because of the gas turbine fuel's affinity to water, special system installation requirements are necessary for quality control of the fuel, such as two-stage filtration, special materials, etc.

The gas turbine fuel is stored in regular ship's tanks. The fuel is transferred via transfer pumps and purifiers or filter/separators to gas turbine fuel service tanks. Delivery of gas turbine fuel to aircraft fueling stations, such as hangar and flight deck stations on an aircraft carrier, is via service pumps and filter/separators. Gas turbine fuel aircraft fueling stations are distributed along the hangar and flight deck areas to serve any aircraft parked in these areas.

3

Damage Control and Hull Preservation

The original stability of a ship and its ability to withstand hull damage and flooding is the business of her designers and builders, but the basic principles of stability and damage control are important to the seaman for his own safety and that of his ship.

3.1. Stability. A ship has two principal kinds of static stability, longitudinal and transverse; the first tends to keep a ship from rolling end over end; the second tends to keep her from capsizing. Longitudinal stability is always enough to avoid danger, although poor longitudinal stability characteristics may cause discomfort by excessive pitching and make a very wet ship. The knowledge of the transverse stability of any ship, on the other hand, is important to the seaman in order to gauge the amount of roll allowable without danger of capsizing.

Unless acted upon by some external force, a ship that is properly designed and loaded remains upon an even keel. A righting moment which develops when the vessel rolls tends to return the ship to an even keel. The righting moment is the product of the righting arm (defined later) and the force of buoyancy. The force of buoyancy is the sum of the vertical components of the hydrostatic pressure on the underwater body. It is also equal to the weight of the water displaced by the underwater body. The force of buoyancy also keeps the ship afloat, but it may be overcome and the ship sunk if too much weight is introduced, as is the case when too many holds or compartments are flooded. The righting moment tending to bring the ship back on an even keel may be overcome and the ship capsized if too much weight is introduced on one side of the centerline, as when all compartments on one side are flooded. A ship may also capsize when it is stranded and the righting arm becomes negative due to reduction of the underwater volume and the upward force acting at the point of stranding.

The foregoing examples are static forces tending to capsize a ship. The effects of wind and waves are dynamic forces. A smaller dynamic force than static force may be sufficient to overcome the righting arm and to capsize a ship because the effect of a dynamic force depends on the speed with which it is applied as well as on its magnitude. A common example is that a boat under

sail may be capsized by a sudden squall when it might weather perfectly a wind of the same force that came up gradually.

An elementary idea of the forces tending to prevent a ship from capsizing can be obtained from (a) and (b), Fig. 3.1. In (a), G represents the center of gravity of the ship. It is the point where the sum of the moments of all the weights of a ship with reference to any axis through this point are equal to zero. In other words, the ship acts as though all its weight were concentrated. Because the loading is usually the same on both sides of the vertical centerline plane, G usually lies in this plane and, in ships of conventional form, near the

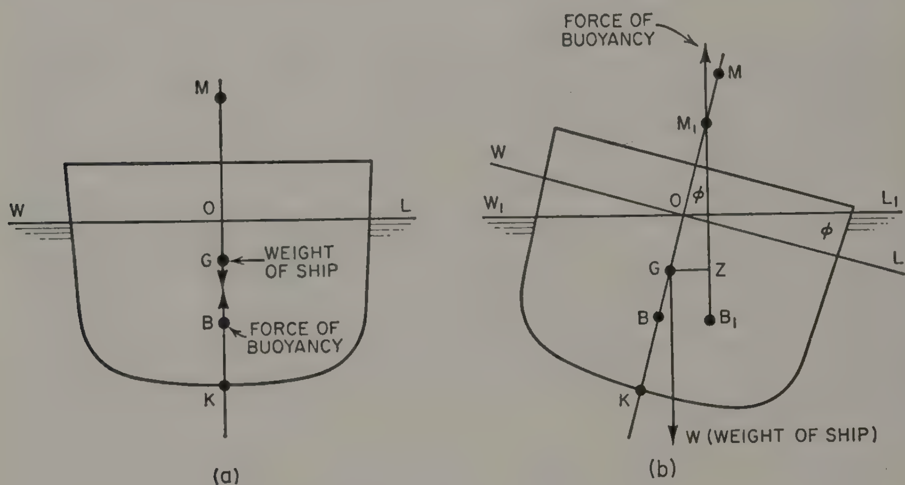


FIG. 3.1 FORCES ACTING ON HULL

water line. The center of gravity does not shift vertically if weights are added or subtracted whose algebraic sum lies in the same horizontal plane as the center of gravity. It is raised if the sum of the weights added lie above this plane, or the sum of the weights subtracted lie below it. Conversely, it is lowered if the sum of the weights subtracted lie above it, or the sum of the weights added lie below it. The pertinent formula is:

$$KG_1 = \frac{WKG \pm w_1Kg_1 \pm w_2Kg_2 \cdots \pm w_nKg_n}{W \pm w \pm w_2 \cdots \pm w_n}$$

where KG_1 = new height of center of gravity above the keel
W = original displacement of ship
KG = original height of center of gravity above the keel
w_1 = weights added or removed
Kg_1 = height of w_1 above keel

The symbol B is used to indicate the ship's center of buoyancy which may be considered as that point through which the resultant of all upward forces is

considered to act and which lies in the geometric center of the underwater form of the vessel. When the ship is on an even keel, B is in the vertical longitudinal centerline plane, and the upward force of buoyancy is directly under the point G where all the weight of the vessel is considered to be concentrated. When the ship lists or rolls, B moves to the lower side, and a vertical line drawn from B cuts the vertical plane of the centerline. The point M, where this line cuts for an infinitesimal angle of inclination, is called the metacenter, and distance GM is called the metacentric height. BM is called the metacentric radius and is mathematically equal to I/V, where I is the moment of inertia of the water-line plane and V is volume of displacement.

For any given condition of loading, G may be considered as fixed, but both B and M move as the vessel heels. In (b) the ship has heeled to the right an angle of ϕ degrees, and B has moved to B_1, the center of gravity of the volume of liquid displaced in this new position. A vertical line through B_1 cuts the centerline at M_1, the new position to which the metacenter has moved. A perpendicular line drawn from G to the intersection of line B_1M_1 (point Z) is the righting arm and is indicated by the symbol GZ. As can be seen, it is the distance between the lines of action of the force of buoyancy B acting up and the force of gravity acting down. The righting moment is equal to the value of the couple set up by W and B. Its value is $W \times GZ$ or $B \times GZ$, where W is the weight of the ship.

As the ship heels over further, M_1 moves down the centerline, and the distance GM_1 decreases by an amount varying with the characteristics of the individual ship. Theoretically, M_1 could move below G and the righting arm GZ become negative, but in practice other factors could usually capsize the ship before this point is reached. The angle at which GZ becomes negative is the upper limit of the range of stability.

As the angle of inclination increases, the length of the righting arm increases for a time until it reaches a maximum, after which its length decreases due to the movement of M_1 down the centerline. The righting moment varies directly as the righting arm, since W remains constant; hence it, too, increases until it reaches a maximum after which it decreases sharply. This is called the point of maximum righting arm.

The preceding paragraphs give a very rough idea of the forces tending to prevent a ship from capsizing. All the factors involved are treated thoroughly under the science of naval architecture. Cross curves of stability show the ship's static stability characteristics (i.e., righting arms, range of stability, etc.) for different displacements at an assumed position of center of gravity. Curves of form show geometric characteristics for different drafts (such as displacement in fresh and salt water, and KM). GM may then be calculated from the relationship $GM = KM - KG$, provided the weight effects have been evaluated. Even more practical, a stability diagram may be solved. It is emphasized, however, that KG and KM must *both* be known, before an appraisal of ship stability is accurate.

A stiff ship may not have as great a range of stability as a ship which has an easier roll and has positive stability at greater angles. She is hard to roll initially because of her greater metacentric height but may have a much smaller range of stability. For instance, an aircraft carrier is a very steady platform and has several times as great a metacentric height as a destroyer, but her range of stability is less, and consequently she cannot roll to as great an angle with safety. Because of the great displacement W of a carrier, the righting moment $W \times GZ$ is also large and would never be exceeded under any conditions, even after extensive damage to the watertight shell.

The addition of weight above the center of gravity decreases the metacentric height and consequently the range of stability. The same effect is caused by removal of weight below the center of gravity. The most common example of this is in ships when the fuel tanks are emptied without admitting water ballast for compensation.

Wind and waves are usually dynamic forces. Sudden strong gusts of wind or heavy seas, especially in shallow water, may build up a dangerous roll when the same force applied as a steady pressure would cause no trouble. A rough method of keeping out of trouble is to watch the period or time required for a complete roll from side to side. The period should remain approximately the same regardless of the magnitude of the angle or roll. Should the period increase appreciably, or the ship appear to hesitate at the end of the roll before coming back, she is probably approaching or past the position of maximum righting effect, and immediate steps should be taken to decrease the roll by changing course or speed or both.

Certain artificial methods are sometimes used to reduce a ship's roll. Rolling keels or bilge keels are built-up structures of roughly triangular cross section attached outside the hull near the turn of the bilge and extending part of the length of the ship. These false keels have the function of damping the roll of the ship. More effective devices are antirolling fins (*Sperry Gyro-Fin* or *Denny-Brown Stabilizer*) which are adjusted by machinery inside the hull and passive anti-roll tanks which use the force of contained liquid, moving out of phase with the ship's motion, to dampen the ship's roll.

To sum up this discussion, the seaworthiness of a vessel is dependent on three things:

1. Its initial and overall stability. Initial is the resistance of a ship to initial heeling when on an even keel. Overall stability is the resistance of a ship to heeling caused by static forces throughout her range of stability.

2. Its range of stability. Range of stability is the total angle through which the righting arm is positive. It is the angle of heel either to port or starboard through which a vessel tends to return to an upright position.

3. Its dynamic stability. Dynamic stability is the righting energy available to resist heeling through an angle not greater than the range of stability.

Initial stability is measured by the transverse metacentric height in feet

which is the distance from the center of gravity up to the metacenter. The center of gravity and the KM remain fixed for any particular condition of loading. Both may change for different loadings with a resulting change in the metacenter height (GM). Any change in this can be quickly estimated by the formula:

$$GM = \frac{0.44B^2}{T^2}$$

where GM = the transverse metacentric height in feet
B = ship's beam in feet
T = time in seconds of a complete roll; e.g., port to starboard to port

NOTE: The constant 0.44 represents an average for various hull forms.

Thus if the period of the roll is doubled, the GM is quartered, and in all probability the ship is in danger. The decision to abandon a ship or to attempt to save her is based greatly on this new calculated GM.

This GM can be increased by lowering the center of gravity by completely flooding some of the lowest tanks and by casting overboard top hamper, boats, torpedoes, spars and mast. The removal of any free surfaces by the complete flooding or pumping of fresh water or fuel-oil tanks, and the removal of water in the bilges will increase the GM, especially if the tanks run athwartship.

A ship with a long, easy roll makes a good platform and a good passenger ship, but the very fact that she has an easy roll is a sign of a low metacentric height. A ship with a large GM will have a quick, jerky roll which is uncomfortable. Beam has a great effect on initial stability (GM) since the moment of inertia of the water-line plane is a geometric function of the beam.

Static stability for any angle is measured by the righting arm at that angle of inclination. As a ship is inclined, this arm increases until it becomes a maximum approximately when the main deck waterways are awash. Further inclining decreases this arm until, at about twice the angle at which the arm was a maximum, it becomes zero and the vessel will no longer right itself.

This last angle gives the range of stability of a ship and totals approximately twice the angle at which the main deck waterways are awash. Therefore, a high freeboard as compared to the beam is desirable. Between two different types of ships, the relative range of stability is measured by the ratio of freeboard and beam; whereas between two ships with the same ratio of freeboard to beam, the GM is the measure of the relative range of stability. Merchant ships with their high freeboard compared to their beam are very seaworthy, even though they have a low value for their GM.

The work utilized in the inclining of a ship is the measure of its dynamic stability. If the force of the sea acting on a ship becomes great enough to heel her over until the righting arm becomes zero, the ship will not be able to right itself. The apparent force of the sea is greatest when the period of the ship and that of the waves are in synchronism, thereby building up a much deeper

roll. This force can be controlled by the ship changing course or speed or both, which alters the apparent period of the waves relative to the ship.

3.2. Tonnage of Ships. As there is sometimes confusion as to the difference between displacement and the several kinds of tonnage, the following definitions are given:

Displacement. The weight of the volume of water displaced by a ship is called her "displacement" and is normally expressed in tons. A cubic foot of sea water weighs 64 pounds, and of fresh water 62.5 pounds; therefore, a ton is equal to 35 cubic feet of sea water or 35.9 cubic feet of fresh water. Displacement tons are always 2240 lb.

Tonnage, Gross Register. The total enclosed space or internal capacity of a ship expressed in tons of 100 cubic feet each is the gross register tonnage. The unit of volume is that figure which was used originally in "Moorsom's System" of measuring ships, and this system has, with slight variations in application, been adopted by most of the nations of the civilized world.

Gross register tonnage is used for calculating net register tonnage in the United States as a basis for drydock charges for steamers.

Tonnage, Net Register. The actual earning power of a ship is expressed by the net register tonnage, and this figure is secured by deducting from the gross tonnage such spaces as may have no earning capacity: for instance, the engine, boiler and shaft alley spaces, coal bunkers, spaces used in steering and working the ship, and such spaces as may be necessary for the accommodation of the crew. The laws of the several nations vary with reference to the various deductible spaces. Net register tonnage is generally used in charging harbor dues, canal tolls, and other similar charges to which merchant ships are liable.

3.3. Load Line Markings.[1] In accordance with the International Load Line Convention, 1930, and an Act of Congress passed in 1929, load lines were established for merchant vessels of 150 gross tons or more proceeding to sea on an international voyage. (Special load lines for vessels engaged in voyages on the Great Lakes and in Coastwise Voyages by Sea are in conformity with the Coastwise Load Line Act, 1935, as amended in 1936, and apply also to all merchant vessels of 150 gross tons and upwards.) These load lines indicate the drafts at which, for various conditions and types or classes of vessels, there will still be left a sufficient percentage of reserve buoyancy to ensure the safety of the vessel. On it are indicated the maximum safe drafts for fresh and salt water, for winter and summer, and for certain oceans.

As provided in the Load Line Act of 1929, the American Bureau of Shipping assigns load lines and issues load-line certificates. The authority by whom the load lines are assigned may be indicated by letters marked alongside the disc and above the centerline (Fig. 3.2).

[1] The earliest load line markings, still found on all British merchant ships, are called Plimsoll marks after Samuel Plimsoll, by whose efforts the act of Parliament to prevent overloading was procured.

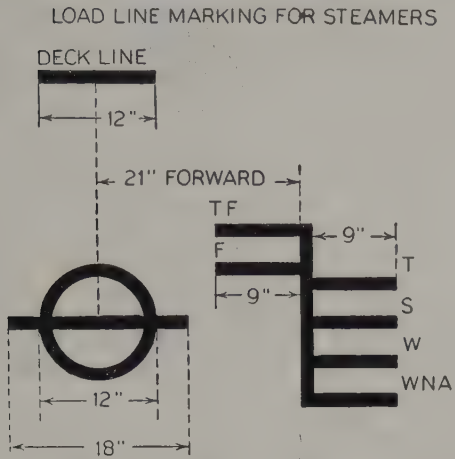


FIG. 3.2 EXPLANATION OF SYMBOLS OF THE LOAD LINE MARK FOR CARGO STEAMERS AND TANKERS

TF—Tropical Fresh Water Load Line
F—Fresh Water Load Line
T—Tropical Load Line
S—Summer Load Line
W—Winter Load Line
WNA—Winter North Atlantic Load Line

3.4. Pressure. Hydrostatic pressure on a submerged body, such as the hull of a ship, is proportional to depth and acts at right angles to the surface of the hull. Each square foot of surface of the hull is subject to a pressure of $\frac{1}{35}$ ton for every foot of depth (or 64 pounds per foot of depth). This water pressure is applied to the hull and transmitted through the frames, decks, and bulkheads to the various parts of the ship. Although the horizontal pressures of water exerted on each side of the ship cancel each other, the force still acts on the hull. The decks and transverse framing and bulkheads prevent lateral crushing of the hull.

If the skin of the ship is ruptured, the hydrostatic pressures formerly exerted on the plating are now imposed on the bulkheads of the flooded compartments. This is why all bulkheads require stiffeners to prevent them from bulging, and why bulkheads well below the water line are thicker, require more stiffeners, and are subjected to higher test pressures. Flooding water will exert a considerable *upward pressure* against the overhead deck of a flooded compartment if the deck in question is some distance below the water line.

Hull Damage Control

The stability principles considered in this chapter are useful to the seaman to the extent that they explain in general why the undamaged, properly loaded

ship remains upright in heavy weather. They also reveal the range and type of response that may be expected from the undamaged ship. If damage occurs it is necessary to apply these principles quickly to save the ship. In the application of these principles it is important to realize how damage may reduce margins of buoyancy and stability. Damage sustained by vessels in peacetime accidents is often similar to the effect of wartime enemy action; a peacetime collision with possible attendant fires and explosions may be just as serious as enemy hits.

After serious damage or in heavy weather the captain must be guided by three factors if he is to save his ship: He must maintain *power*, *buoyancy*, and *stability*. The damaged ship sometimes may be able to survive in calm waters by maintaining only buoyancy and stability. But it may often be impossible to do this without power. Flooded engineering compartments or water reaching main switchboards (through flooding or through ventilators) are important causes for power loss.

3.5. Overall Consequences of Hull Damage. War experience has shown that whenever a ship suffers damage involving serious flooding, either the damage is so extensive that the vessel never stops listing or settling in the water, going down within a few minutes, or the vessel stops heeling, changing trim, and settling in the water shortly after initial damage.

Experience also shows that vessels which survive several hours after damage and then sink, suffer PROGRESSIVE flooding whose control requires proper training of the crew. This flooding comes about in the following manner:

As a result of a hit or collision a large hole is opened in the side. Several bulkheads and decks may be carried away just inside this hole. Immediate flooding occurs through these large holes, giving the ship her initial list, trim, and reduced stability.

In addition to the large holes, there may be a certain amount of subsidiary damage, with riddled or warped bulkheads and decks, opened seams, leaking doors and hatches, etc. These permit slow leakage and progressive flooding past the boundaries of the damage. The slow flooding is aggravated if personnel escaping from the damaged area leave doors or scuttles open behind them.

3.6. Action Before and After Damage. The preparedness before any damage is sustained will often determine whether or not efforts to save the ship afterward can be successful. As a rule, men-of-war are better able to cope with damage. They are usually more fully compartmented than merchant ships and have more men and equipment to rally against the damage. There has been an increasing tendency both to design and to operate merchant ships with a higher capacity to resist damage. And on both naval and merchant ships there has been a growing understanding that the captain or master has a vital primary role in ensuring such preparedness against damage at sea. This preparedness consists generally of:

1. Utilization of designed hull safety features at all times when at sea (such as ensuring that watertight boundaries are faithfully maintained).

2. Ensuring that the ship is not overloaded.
3. Ensuring that deck loads are not exceeded.
4. Ensuring proper amount and distribution of liquid and other cargo and ballast.
5. Ensuring that crew members are trained to localize damage insofar as facilities of the ship permit.

The loss of the *Andrea Doria* is well known by mariners as an example of how improper liquid loading can doom a ship to sinking. When one of her huge, off-center, empty fuel tanks ruptured and filled, the *Andrea Doria* suddenly increased her list nearly 20 degrees.

There exists, in any situation where the vessel does not sink immediately, an excellent chance of saving her if slow leaks can be patched and plugged. Bulkheads that have not collapsed under the blast and onrush of water from the hit are not likely to collapse under hydrostatic pressure.

Immediately after serious damage TWO IMPORTANT DECISIONS must be made: (1) Whether all hands should remain aboard, all but the salvage party should be evacuated, or all hands should abandon ship; and (2) what corrective measures will improve the situation instead of making it worse. The first of these decisions is made by the captain, but his conclusions must be based on information that he receives from the engineer. The second decision is frequently the problem of the engineer unless it involves ship handling or loss of military efficiency (as through jettisoning ammunition).

3.7 The Enemies of Stability. If a ship's tank or void is only partially full, the liquid contents may "slosh" back and forth with the motion of the ship. This effect is known as *free surface.* A similar effect is noted if a compartment is partially flooded.

If the hull is ruptured so that one or more compartments are open to the sea, *free communication with the sea* results.

Free surface and free communication with the sea are, when combined, the deadly enemies of stability.

There is little excuse for free surface; tanks partially full should generally be ballasted. The captain who takes his ship into heavy weather with free surface in his tanks is foolhardy. The ship with initial free surface which is damaged so that it also acquires loose water and free communication with the sea will almost surely be in danger. Free surface should be avoided, since it always causes a reduction in GM and overall stability. (It should be remembered that a reduction in GM reduces a ship's stability.) Free communication with the sea not only reduces GM, *but GZ as well.* Thus, some initial stability is not only lost but, since GZ decreases, there is a decrease in the ship's righting moment.

Care and Preservation. Without proper care, both wood and metal hulls would rapidly deteriorate to the point where they would be unsafe and unusable. Wooden hulls are subject not only to rot and deterioration when not properly protected from the atmosphere, but also to damage from marine

animals and marine growths that attack the underwater body. Metal hulls must be protected from both corrosion and erosion in order to maintain their seaworthiness.

Marine animals and marine growths which damage the hull of a ship or retard its speed are natives of salt water and, generally speaking, are more common and damaging in tropical waters than in colder climates. The greatest hazard to wooden hulls is the teredo or marine borer, a wormlike mollusk which eats its way through wood and riddles planks and timbers with small holes. Like all marine animals and growths, the teredo is poisoned by copper and its derivatives, and the standard protection for wooden hulls is to cover them with a copper base or similarly poisonous paint. Originally a tropical pest, the teredo has spread until it is now found in virtually all salt-water harbors of the United States.

The underwater pest which causes the most trouble on steel hulls is the barnacle, although mussels and marine grasses of various sorts are also found attached to the underwater body. The barnacle is a univalve mollusk which attaches itself tightly to the skin of the ship and forms a shell that is roughly cone-shaped. It propagates freely and if undisturbed will soon build up a layer several inches deep. Barnacles and other marine growths apparently do little damage to a steel hull, except to destroy the protective paint and allow sea water to promote corrosion, but they may reduce the speed of a ship as much as several knots by increasing skin friction between the water and the hull. Modern plastic paints, applied hot in drydock, protect a hull from barnacles for several years.

The greatest problem in the care and preservation of metals is corrosion. Corrosion is the gradual disintegration of a metal due to chemical or electrochemical attack by atmosphere, moisture, or other agents. There are many different types of corrosion. A technical discussion of the various types may be found in any standard reference work on the subject.

Although a ship does not encounter any corrosion problems which may not be found anywhere else, it does encounter virtually all types of corrosion. A bronze propeller secured to a steel shaft and turning in an electrolyte (sea water) introduces the possibility of electrochemical attack on the shaft and the ship's hull. The propeller itself may suffer from cavitation and corrosion-erosion attack. Pumps handling sea water are subject to similar conditions. Propeller and pump shafts are also subject to corrosion fatigue.

The hull and superstructure of the vessel are usually of plain carbon steel, and any seaman knows the amount of chipping and painting necessary to combat the severe rust caused by a marine atmosphere. Some superstructures have been built of aluminum alloys which resist atmospheric corrosion.

The various means for preventing or minimizing corrosion may be classified under four headings:

1. *The use of alloys that resist attack by the particular environment.* The resistance to atmospheric attack of such materials as the copper base alloys,

stainless steels, and Monel metal are well known, but there is no single alloy that is immune to all corroding media. However, the addition of alloying elements in even small amounts may greatly improve the resistance of a particular material to a given environment. About 0.25 percent copper added to a carbon steel doubles its resistance to atmosphere corrosion. Copper-nickel is an excellent material for condenser tubes, but its resistance to sea water is greatly improved by the addition of 0.2 to 0.6 percent iron. Depending on environment, the corrosion resistance of stainless steels may be improved by small additions of manganese, silicon, columbium, titanium, molybdenum, or nitrogen.

2. The use of galvanic protection. The electrochemical mechanism may be utilized for protecting a structural metal in contact with an electrolyte. This galvanic protection consists of attaching to the structure a metal, anodic to the one to be protected, thus sacrificing the added metal and protecting the structure. Zinc is commonly used to protect steel, cast iron, brass, and bronze. The zinc must be in good, electrical contact with the metal to be protected and the electrolyte. Galvanic protection is used for propeller shafts, rudders, and hull plates by attaching zinc plates near the propellers.

3. The control of environment. Metals have very low corrosion rates in dry gases and in pure water free from air. An outstanding example of control of environment is the dehumidification done in the moth-balling program carried out by the armed forces since the end of World War II. The sealed interiors of ships were kept dry with air-conditioning machines; guns, tanks, planes, etc., were completely sealed in moistureproof covers and provided with moisture-absorbing agents.

4. The use of protective coatings. These may be divided into three classes: (a) chemical coatings, (b) nonmetallic coatings, and (c) metallic coatings.

Chemical coatings are those that are formed by chemical reaction between the metal surface and an appropriate solution. The application of phosphate coatings to the ferrous metals is representive of this group. The part to be protected is dipped in or sprayed with a solution of metallic phosphates, and the coating that forms is not only resistant to atmospheric corrosion but serves as an excellent base for paints. Some magnesium and aluminum alloys are similarly protected with chromate coatings. Oxide and silicate coatings may also be chemically produced on certain metals.

Nonmetallic coating materials include paint, varnish, plastics, natural and synthetic rubbers, bituminous, and petroleum products. In general, these materials form a mechanical film to exclude air and moisture from the metal surface. Their effectiveness depends on the initial cleanliness of the metal and on the film thickness. All of them may be satisfactory for prolonged periods of time, depending on environment and whether or not the surface is subjected to abrasion.

Metallic coating processes serve to cover a corrodible metal with a thin layer of another metal which is more resistant to attack. Sometimes the coating also

provides galvanic protection, as is the case with zinc or cadmium coatings on the ferrous metals. Metallic coatings may be applied by electroplating, hot dipping, or metallizing.

Electroplating consists of making the clean base metal the cathode in an electrolytic cell containing a water solution of some salt of the metal being deposited. Close control of the process is essential to good nonporous plating. Copper, nickel, chromium, cadmium, and zinc are electrodeposited on iron and steel as corrosion preventives.

Hot dipping consists of immersing the cleaned base metal in a molten bath of the coating metal. The process is suitable for those metals that will wet each other. Zinc and tin coatings are commonly applied by hot dipping.

Metallizing is a metal spraying process in which a wire or powder of the coating metal is melted by an oxyacetylene flame in the presence of an air jet which atomizes the metal and sprays it onto the base metal. The base metal must have a roughened surface since the bonding is purely mechanical. Virtually all metals can be sprayed, and the process is used to build up worn parts and provide hard surfaces as well as for corrosion resistance.

3.8. Drydocking. The protective measures just described for the underwater hull cannot be used at discretion, as is done in the case of surfaces above water. The submerged hull is virtually inaccessible while the ship is waterborne. No protective coating that will last indefinitely under water has ever been devised and it is unlikely that one ever will be. Damage to underwater fittings may occur that will remain undetected as long as the fittings remain submerged. The only practical method for preserving the underwater hull is to remove it from the water at intervals, make needed repairs, and give it the best protective coating available before refloating. This routine is generally known as drydocking.

There are several methods of drydocking. The oldest and simplest is known as beaching and careening. This process consists of putting a ship on a shelving beach at high tide, working on alternate sides during periods of low tide by heeling her over at an angle with tackles made fast from some solid object to her spars, and finally hauling her off during a subsequent period of high water. This method will never be seen in modern practice, except in the case of very small vessels or possibly for temporary repairs in a case of accident or emergency. For the ordinary steel vessel the usual methods of drydocking are by the use of marine railways, floating drydocks, and graving docks.

A *marine railway* is an inclined shipway by means of which a vessel of moderate size, resting in a cradle, can be drawn out of the water above the reach of the tide. The cradle is on wheels that run on rails and is moved by means of a windlass and endless chain. Few marine railways will handle a ship larger than a moderate-sized destroyer.

The usual *floating drydock* (Fig. 3.4) is made up of rectangular, open-ended sections that can be fastened firmly together. Tanks are flooded with

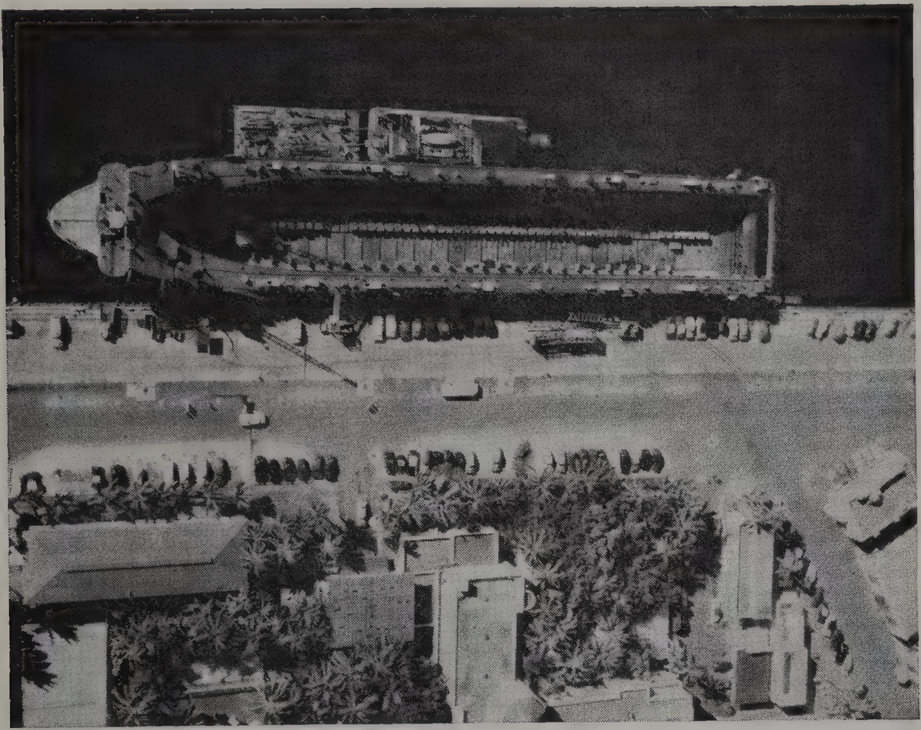


FIG. 3.3 AUXILIARY REPAIR DRYDOCK: EMPTY, WITH SUPPORTING CRAFT ALONGSIDE. *Official U.S. Navy Photograph*

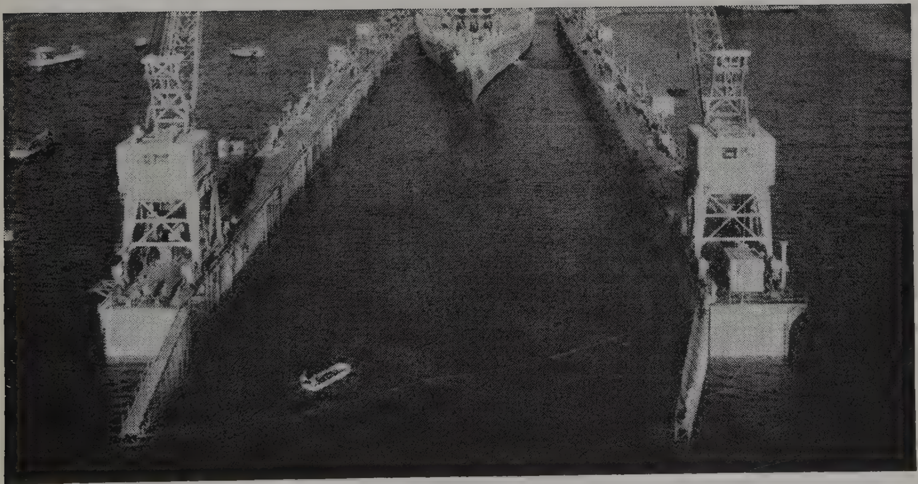


FIG. 3.4 FLOATING DRYDOCK IN FLOODED POSITION RECEIVES A SHIP FOR SERVICING. *Official U.S. Navy Photograph*

water to sink the dock far enough for a ship to enter the cradle and then are pumped out so as to raise the ship and the inner part of the dock clear of the water. By using enough sections of suitable dimensions, all but the largest types of ships can be docked. Sections of the dock also can be used to dock each other. One of the great advantages of floating drydocks is that they can be towed to the localities where they are most needed. Mobility of floating drydocks has been increased greatly in the types of construction developed by the U.S. Navy in the past few years. Floating drydocks for the smaller types of vessels are built in one piece with the usual ship type bow and are equipped with a steering mechanism. A section with a ship type bow for ease in towing may also be provided for larger sectional floating drydocks. Most floating drydock sections are self-contained. They have pumps for emptying their ballast tanks, power plants and other facilities for the storage and distribution of such services as oil, compressed air, steam, and electric current; and may be equipped with machine shops and with quarters for their crews.

A *graving dock* (Fig. 3.5) is a permanent installation in a shipyard. It is a narrow basin having walls and a floor, usually built of reinforced concrete,

FIG. 3.5 PARTIAL VIEW OF A RATHER PRIMITIVE GRAVING DOCK IN THE FAR EAST. *Official U.S. Navy Photograph*

into which vessels may be floated and from which the water may be pumped out, leaving the vessels dry and supported on blocks. It is used for repairing and cleaning the underwater hull of ships and in some cases for building ships.

Graving docks are built at an angle to the shore line, and one end must be

open to navigable water in order to allow the entrance of ships. This open end is usually closed by a caisson, either floating or sliding, although in some docks a double swinging gate is used. The most usual type, the floating caisson, is a self-pumping hollow gate which is floated and towed clear when the dock is flooded. After a ship enters the dock the caisson is moved into place and flooded with water, which causes its ends to sink into wedge-shaped grooves cut in the walls of the dock while its base fits against and is supported by the sill, which extends across the entrance of the dock and is raised somewhat above its floor. The depth of water over the sill at high tide determines the greatest draft of any ship that can be docked. In a naval shipyard dock especially, it is desirable that this depth be greater than the ordinary draft of any ship it is expected to accommodate in order to allow for the increased draft due to battle damage.

The walls of a graving dock are usually built in steps which are known as altars. Power capstans and fixed bollards are installed to control the lines used in hauling the ship in and out of the dock. Blocks are heavy wooden structures used to build up the cradle in which the ship rests while in dock. The keel blocks, upon which the ship's keel is supported, are large cube-shaped, semi-fixed structures built up of concrete, hardwood, and soft pine caps. Other blocks, called bilge blocks, can be hauled in and out to the desired position on tracks set at right angles to the center line. Docking keel blocks are the blocks upon which a vessel's docking keels rest. Should a vessel have no docking keels and insufficient flat bottom for the installation of enough blocks to keep her upright, wale shores may be used. These are spars extending from the ship's side to the side of the dock and wedged in place as she settles upon the keel blocks. In case several small vessels are to be docked at once, blocks may be set up for them on appropriate sections of the dock floor.

3.9. Preparations for Docking. In preparing a dock to receive a vessel, the dockmaster or docking officer first refers to the ship's docking plan. This furnishes necessary information concerning the underwater hull for docking purposes. For United States men-of-war a copy will usually be found in the files of the ship's home yard, but every ship should carry its own docking plan. To place the blocks accurately and to build them up to the proper height and bevel, the docking plan must give the following information:

1. Full extent of keel with flat and rising portions accurately delineated.
2. Peculiarities of stern post and rudder.
3. Sections, amidships and elsewhere, to show proper height and bevel of bilge blocks, if these are necessary.
4. Shape and location of keels, docking keels, struts, propellers, underwater fittings, and projections of all kinds.

Further, since it is often necessary to provide more blocks than usual under heavy weights, the docking plan should show:

5. Location of boilers, engines, and other unusual weights.

To assist in locating sighting battens the plan should show:

6. The length on the load water line.

Finally, in order to enable the dockmaster to determine whether or not the dock can take a ship, or to place her accurately in the dock, the plan must show:

7. The length overall, the beam, and all projections, such as blisters, increasing the normal beam.

3.10. Docking. The dockmaster of any particular dock, knowing the ship's draft, the maximum depth over the sill, and the current and tidal variations in the vicinity, decides on the time the ship should enter the dock and so informs the commanding officer. The commanding officer makes the necessary arrangements to ensure that at the time specified the ship is without any list to either side and with trim, if any, as specified by the dockmaster or docking officer.

The dock being already prepared, water is admitted, the caisson is floated and removed, and the ship is brought to the dock entrance, usually with the assistance of tugs. When the bow of the ship has safely crossed the sill of the dock, the responsibility for her safety rests upon the dockmaster, who hauls her into the dock, replaces and sinks the caisson, centers the ship, starts dock pumps, and proceeds with the docking until the ship is safely landed on the blocks and the dock is pumped dry.

Should any extraordinary conditions exist, such as those due to accident or battle damage to the ship, the special precautions taken in docking her must depend upon the judgment of the dockmaster.

No change of any kind in her weights during the period when the ship is in dock should be made without the knowledge and consent of the dockmaster. Improper changes in weights may cause her to do serious damage to herself or the dock when she is floated, due to sudden changes in list or trim.

3.11. Routine Work in Drydock. The following routine drydock work is done in addition to any special underwater repairs or alterations decided upon:

1. Clean bottom, including scaling or wirebrushing of badly corroded parts.
2. Cut out and re-drive all loose or badly corroded rivets.
3. Caulk leaky seams and rivets.
4. Overhaul underwater valves.
5. Repack underwater stuffing boxes.
6. Renew zinc and mild steel protectors as necessary.
7. Take propeller shaft clearances and re-wood stern and strut bearings as necessary.
8. Check pitch of propellers, clean and polish them.

9. Examine rudder pintles and gudgeons and rudder shaft packing. Take rudder bearing clearances.
10. Paint bottom, paint draft marks, paint boot-topping.

3.12. Undocking. After all underwater repairs are completed and the bottom is painted, a time for flooding the dock is agreed upon between the commanding officer of the ship and the dockmaster. The former stations men at the outboard valves and elsewhere as he deems necessary, to ensure that water does not enter the ship. The latter stations men at the various shores and lines to prevent as far as possible any injury to the ship or dock from a change of weights or any unexpected alteration in tide or wind.

Water is admitted to the dock under the dockmaster's control. When all sea-valve openings are covered, flooding is usually checked until their watertightness can be reported. When the water has risen to a sufficient height the ship lifts from the keel blocks. When the ship is safely afloat flooding is continued until the water level within the dock is the same as that outside. The caisson is floated as quickly as possible, then removed, and the ship is hauled out of drydock.

4

Propulsion and Steering

A knowledge of seamanship would not be complete without an understanding of the means available to maneuver a ship: the power plant and the steering mechanism. A ship's captain or deck officer must know the minimum and maximum responses of his ship to backing, accelerating, and rudder angle under all conditions. With this knowledge the expert shiphandler will always avoid putting his ship into such a situation that judicious use of his engine and rudder cannot extricate him. Regardless of the apparent complexity, any propulsion device is based on the fundamental principles of energy conversion. The energy available in a fuel, whether conventional fuel such as oil, or nuclear, is converted to mechanical energy, which is then used to give the ship kinetic energy or energy of motion.

4.1. Boilers. Naval boilers supplying steam for propulsion are now mainly water tube boilers. In this type the water is inside tubes within the boilers, and the products of combustion change the water to steam by the transfer of heat through the tube walls. Fire tube boilers, in which the products of combustion are within the tubes and heat is transferred outward to water surrounding the bank of tubes, are now seldom seen in naval service except as auxiliary boilers supplying steam for heating or for evaporators. Water tube boilers, which have replaced the old fire tube boilers, may be of the large tube or small tube (express) type. The latter is found in most modern steam-propelled ships. The small tubes give a greater heat-transfer surface and became feasible when feed-water treatment had progressed far enough that deposits would not block the path of water in the small tubes. Modern boilers can be safely lit off cold and brought up to full pressure in 1 hour, which is quite an improvement over the approximately 8 to 12 hours required by the old fire tube boilers.

4.2. Nuclear Reactors. Heat for turbine propulsion and turbogenerators on the nuclear-powered ship comes not from a boiler but from a *reactor*. It might be easiest to understand the shipboard function of a reactor by considering that it is a type of boiler that consumes a unique fuel which generates heat through the process of nuclear fission.

There is one major difference between boilers and reactors. In the boiler, the water in the tubes is heated directly by the boiler fires. This is not the case in the reactor. Here the heat is initiated and controlled by moving a neutron absorber in or out of the fuel area. The resultant controlled nuclear fission heats

water under pressure (known as a *coolant* because it removes heat from the reactor). The coolant then goes through a heat exchanger known as the steam generator.

Primary or Main Coolant System. The reactor compartment equipment includes a reactor, and a primary loop.

The reactor gives up heat to the main coolant, highly pressurized water, which then is forced through the steam generator where it gives up heat to form steam. The main coolant is then pumped back into the reactor where it is again heated up.

The main coolant water is kept pressurized to ensure that boiling will not take place in the reactor.

Secondary or Main Steam System. The secondary system is the steam system. It is completely isolated from the primary system.

Steam from the steam generator flows back to the engine room where it drives ship service turbogenerator sets and the main propulsion turbines.

4.3. How the Deck Officer Can Promote Efficient Boiler Operation. Some deck officers seem to feel that the engineer's only reason for blowing tubes is to spread fine carbon dust over the clean topside, and consequently they refuse to allow tubes to be blown on their watch. An understanding of the reason for blowing tubes may temper their reluctance to grant the necessary permission. The oil burned in boilers leaves a layer of soot on the outside of the small water tubes previously discussed. This soot is undesirable for the following reasons: (1) The soot acts as an insulator and slows heat transfer to the water within the tubes. (2) If the soot remains in a boiler when fires are secured, it absorbs moisture from the air; the moisture activates the sulfuric acid in the soot, and this acid in turn attacks the metal of the tubes and boiler drum. (3) If allowed to remain too long, the soot packs into a solid mass and can be removed only by tedious hand cleaning. To maintain maximum boiler efficiency, tubes should be blown, while under way, once every 4-hour watch and, while in port, twice a day. When "tubes are blown," high-pressure steam is admitted to perforated tubes (known as soot blower elements) which are permanently installed within the boiler. The elements are rotated so that steam jets from the perforations play on all the tube surfaces within the boiler, cleaning them thoroughly. Tubes should be blown when the wind is abeam. The officer of the deck should also be aware that maximum efficiency usually is served by steaming with a light brown haze.

4.4. Combustion In Internal-Combustion Engines. The fuel for an internal-combustion engine is burned within the engine and the products of combustion pass directly through the engine, resulting in the transformation of heat into mechanical energy. There are basic differences in the three common types of combustion chambers in internal-combustion engines. In the spark ignition, commonly referred to as the gasoline engine, combustion chambers are located in each cylinder and comprise the space between the top of the piston and the top of the cylinder. Fuel is admitted periodically and is ignited

by an electrical spark. The fuel and air are mixed in the carburetor and enter the combustion chamber together. The gasoline engine is seldom seen in naval vessels or boats now because of its extreme fuel fire hazard.

The compression ignition or diesel engine is a reciprocating engine very similar to the spark ignition engine shown in Fig. 4.1. The main differences are that the fuel is ignited in the diesel engine by the high temperature of the highly compressed air in the combustion chamber; air only is taken in on the intake stroke, and the fuel is injected in a fine mist at the start of the power stroke. The diesel engine is used extensively in the Naval Service for main propulsion

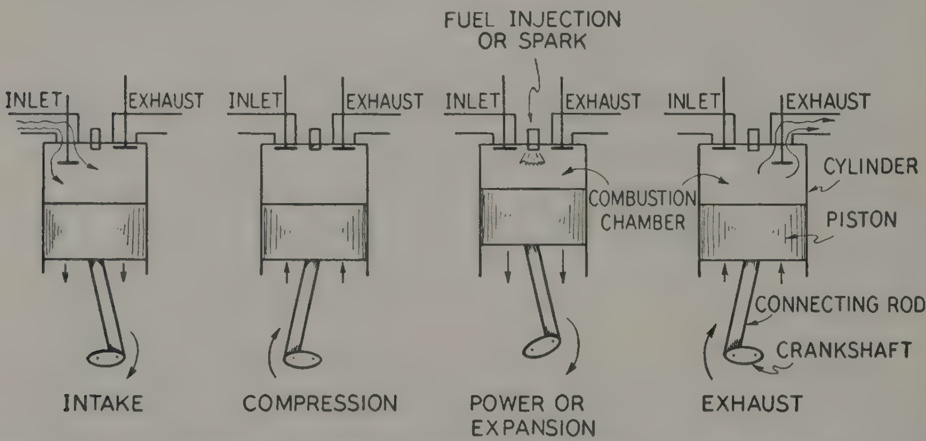


FIG. 4.1 ONE CYLINDER OF A SPARK IGNITION OR COMPRESSION IGNITION ENGINE (FOUR STROKE CYCLE) SHOWING THE FOUR PHASES IN ONE COMPLETE FIRING CYCLE

on ships and boats and for auxiliary or emergency electric generators even in steam-propelled ships.

The gas turbine engine combustion chamber is simple in construction and is merely the container in which air is mixed with a burning fuel. The air and fuel flow are continuous (in contrast to the spark and compression ignition engines), and once the fuel is ignited no further outside spark or high temperature is required to maintain burning. The combustion chamber, although simple, must be designed to provide cooling, proper air and fuel mixing, and freedom from flame "blow-out." A more complete discussion of the internal-combustion engines and their naval applications will be given later in this chapter.

We have seen that energy is extracted from fuels and becomes available for further conversion in the form of a heated working substance, either steam or the actual products of combustion. There will follow a discussion of how the heated working substance is used to produce mechanical energy.

4.5. The Steam Turbine. Steam enters a turbine through nozzles which direct the steam on to moving blades mounted solidly on a rotor. The rotor is enclosed in a casing and supported on bearings at each end of the casing. When the steam has passed through the first row of moving blades, making

them spin, it enters a row of stationary blades attached to the casing which in turn direct the steam against a second row of moving blades attached to the same revolving rotor. Alternate rows of fixed and moving blades are located along the length of the turbine. The steam flows through the turbine because of the pressure difference between the point of entry and the point of exit. As it passes through each set of fixed and moving blades (known as turbine stages), the steam pressure and temperature drop as some of the energy is extracted to make the turbine drum revolve. Theoretically the stages necessary to extract all the energy available between the entering and final steam pressures could be in one casing, but actually such a turbine would be too long, the shaft would tend to sag in the middle, and unequal expansion could take place. Actually, the stages are divided between two or three turbines known as the cruising, high-pressure, and low-pressure turbines. Large ships have only a high-pressure and a low-pressure turbine for each shaft. Destroyers sometimes have cruising turbines as well for economy operation. To provide backing power another turbine is required, designed to turn the shaft in the reverse direction. This backing turbine could be housed in a separate casing, but because of its small power requirement (requiring only two or three stages) in comparison to the ahead power requirement, it is more economical to mount it in the existing turbine casing of the low-pressure turbine which is positioned over the steam condenser.

Turbines are most efficient when running at high speed (3000 to 6000 rpm), whereas most propellers[1] are most efficient at slow speeds (up to about 200 rpm). To allow both to run at their most efficient speed, a reduction gear is used between the turbine and the propeller shaft. The reduction ratio varies but is in the neighborhood of 20 to 1 for large ships.

4.6. What the Deck Officer Should Know about His Turbines. When the officer of the deck gives permission to the engineers to start warming up the main plant he should know that the engines are slowly turned by the jacking gear. The jacking gear consists of an electric motor and a hand-operated gear clutch which can be connected to the reduction gear. The clutch is connected, and the electric motor is started, which turns over the turbines slowly and the propellers even more slowly. While no way is put on the ship by this, the OOD should make sure that nothing can foul the propellers in their slow revolving before he grants permission to warm up.

Approximately 15 minutes before the time set for getting under way, the engineer officer of the watch will request permission to "Spin main engines with steam and to continue spinning at 5-minute intervals." The officer of the deck should realize that it is only the engines that are "spun" and not the propellers. A quick puff of steam sufficient to start the turbines rolling is admitted from the ahead throttle, and, as soon as the turbines start, the ahead throttle is closed and the astern throttle is opened, stopping the spin. The propeller may

[1] Propellers will be discussed in more detail in a later section of this chapter.

turn only a fraction of a revolution, but no way should be put on the ship from this spinning.

The reason for spinning the turbines at 5-minute intervals is to prevent uneven heating of the turbine rotor with the possibility of its developing a sag. With the close fit of the rotor in the turbine casing a slight sag would cause the blades to scrape on the casing and possibly snap off. Before spinning the main engines with steam, the jacking gear must be disconnected. The purpose of jacking is the same as for spinning with steam. Whenever the engines are stopped, they should be spun every 5 minutes. When word is given to secure the plant, the jacking gear is again engaged, and the turbines are jacked over until cooled.

4.7. Locking a Shaft. If one engine or propeller is damaged while a ship is under way, and the ship cannot be stopped, the damaged engine and shaft must be locked to prevent worse damage. If only the steam is shut off, the shaft will continue to turn as the water acts on the dragging propeller. To lock a shaft underway the ahead throttle is closed and the astern throttle is opened enough (steam is admitted to the backing turbine) to stop the shaft from turning; then the jacking gear is engaged and a friction brake on the jacking gear is tightened. The other shaft (or shafts on a 4-shaft vessel) are usually limited in their allowable revolutions when one or two shafts are locked. The limitation is required to avoid overloading the driving turbines and shafts. The limiting rpm's for naval ships are given in the Bureau of Ships Technical Manual which is provided to all ships.

4.8. Diesel Engines. The diesel engine is the most common internal-combustion engine now found in boats. For horsepowers up to approximately 4000 to 6000, it has definite weight, space, and efficiency advantages over a steam plant. The diesel engine can be found as the main propelling machinery in landing ships and craft, small auxiliary tankers and cargo ships, patrol craft, tugs, and non-nuclear submarines. The diesel can be connected either directly to the propelling shaft or connected through a reduction gear to the propelling shaft. Another method is to use the diesels to drive electric generators which supply electricity to drive motors which turn the propeller shafts. This operation will be discussed further at the end of this section.

The direct-connected diesel must be of slow speed in order to allow the propeller to operate at an efficient speed. However, to reduce weight and improve its own efficiency, the diesel should run at high speed. The reduction gear is the logical answer and allows the diesel to turn at its high efficient speed while the propeller turns at its slow efficient speed. Most diesels have a flexible coupling between the engine and the reduction gear of the propeller shaft to prevent engine vibrations from being transmitted to the gears or the shaft. The coupling can be hydraulic—similar in style but larger than those now used in the automobile fluid drive—spring packs, or an electromagnetic device.

4.9. Gas Turbines. The gas turbine holds promise as a lightweight, compact plant which can be warmed up and loaded in a matter of minutes. One of the

main problems involved is to find a material for the turbine blades which will withstand the high temperatures of the products of combustion. Figure 4.2 shows a schematic diagram of a simple gas turbine plant. The engine is started by an electric starting motor; air enters the compressor where its pressure is raised before going to the combustion chamber where fuel is added and ignited. The products of combustion enter the turbine and cause it to turn. The starter is then disconnected and the turbine continues to run, driving the compressor and the propeller. In order for the turbine to develop enough power to drive the compressor and the propeller, the turbine inlet temperature must be high, but the high temperature tends to burn out the turbine and reduce its useful life.

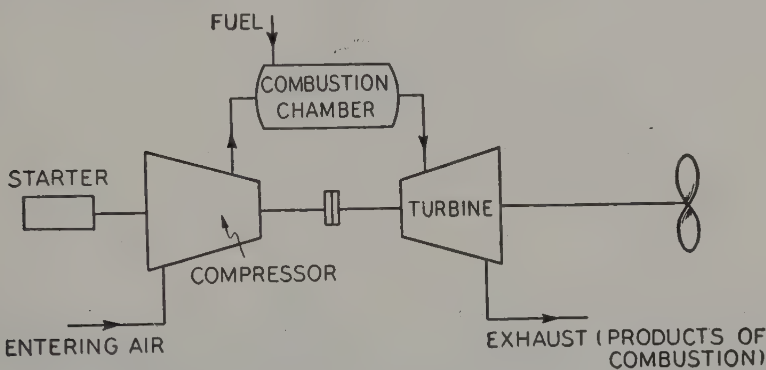


FIG. 4.2 SCHEMATIC DIAGRAM OF A SIMPLE GAS TURBINE PROPULSION PLANT

The gas turbine is most efficient when running at its designed speed and does not necessarily lend itself to variable speed operation. It may have an application as a lightweight, relatively short-lived auxiliary boost plant for a steam-turbine-driven vessel. The steam turbine plant should be used for normal cruising and the gas turbine plant cut in only when highest speeds are required.

4.10. Electric Drive. Any of the propulsion engines mentioned so far could be used with an electric drive. In the electric drive the engines already mentioned drive an electric generator at a constant speed. The generator or generators in turn supply electricity to electric propulsion motors which drive the propeller either directly or through a reduction gear. Reversing the propellers is accomplished by electrical switches which reverse the driving motors. The engine driving the generator can always turn in one direction. The electric switches can be located on the bridge and hence give the officer of the deck complete control of his speed and direction of travel. Diesel-electric tugboats are frequently fitted with this type of control.

4.11. Engine and Steering Controls. The bridge is the primary station for controlling the engines as well as for steering and navigating the ship. In large ships auxiliary control stations are provided with part or all of the bridge control instruments duplicated and with sound-powered telephone

communication with the bridge and the engine rooms. In merchant ships an auxiliary control and steering station is generally located on or above the main deck, in the after part of the ship. In men-of-war, where the chance of battle damage is great, engine and/or steering controls may be found in secondary conning stations (located remote from the bridge) in central control stations or controlling engine rooms, in steering engine rooms, and possibly in other locations. These are discussed in Chapter 7.

4.12. Propellers. After the energy of a fuel has been converted to heat and in turn the heat converted to mechanical energy, a way must be found to use the mechanical energy to drive the ship. The propeller is the device used to drive all large modern ships. The propeller in a fluid, such as a marine propeller, is a device to obtain a reactive thrust by increasing the velocity of the fluid through its disc. It thus changes the momentum of a mass and provides a propulsive force, or reactive thrust. One method of describing a propeller is by the number of blades it has. The usual number is three or four, although propellers are in use having two, five, and six blades. Normally a propeller with more blades will have a smaller diameter for the same "pushing" power than one with fewer blades.

Another method of describing a propeller is by the direction it turns when driving the ship ahead. Obviously we must specify the side from which we view the propeller in determining its direction of motion. By convention, a right-handed propeller is defined as a propeller that turns in a clockwise direction, viewed from astern, when driving the ship ahead. Similarly a left-handed propeller turns counterclockwise viewed from astern, when driving the ship ahead. Ships having one propeller are designated as single-screw ships; ships having two propellers are called twin-screw ships, while multi-screw ships may have three or four propellers. It is most common for ships to be equipped with one, two, or four screws. The blades of a propeller may be fastened to the hub with bolts or may be cast with the hub in one piece.

There is one type of propeller which can reverse the direction of a ship without requiring a change of direction of the drive shaft. This type of propeller is known as a controllable pitch propeller. The blades are mounted so that they can each rotate on a shaft which is mounted in the hub as shown in Fig. 4.3. It is an excellent propeller for making a ship very maneuverable. With the increased application of gas turbine main propulsion which is inherently nonreversible, the controllable propeller is required. Its primary advantages are reversibility and maximum or peak efficiency over wider range of rpm resulting in better economy.

A new propeller promises advances in ships speed with no increase in power. The propeller, shown in Fig. 4.4, was developed by the Navy and is known as a supercavitating propeller. It greatly reduces the *effect* of cavitation, if not the cavitation itself, as can be seen by comparing it with a conventional propeller, Fig. 4.5. Cavitation is the partial vacuum in a fluid about a rapidly revolving propeller. It results in the formation of vapor pockets

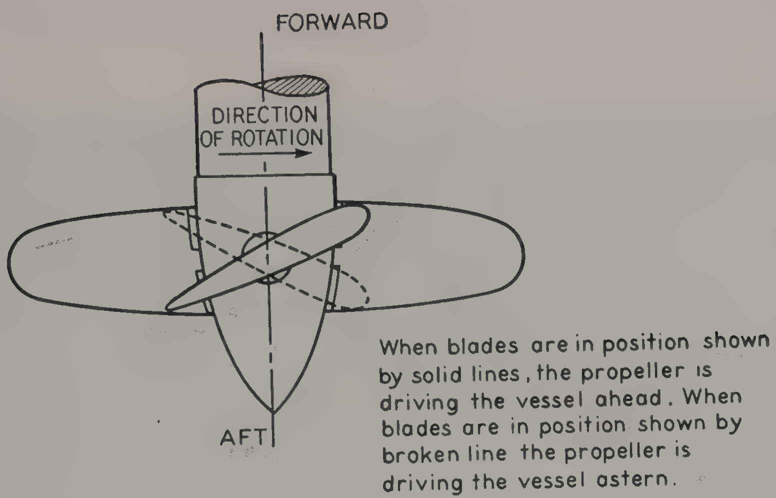


FIG. 4.3 SCHEMATIC DIAGRAM OF A CONTROLLABLE PITCH PROPELLER

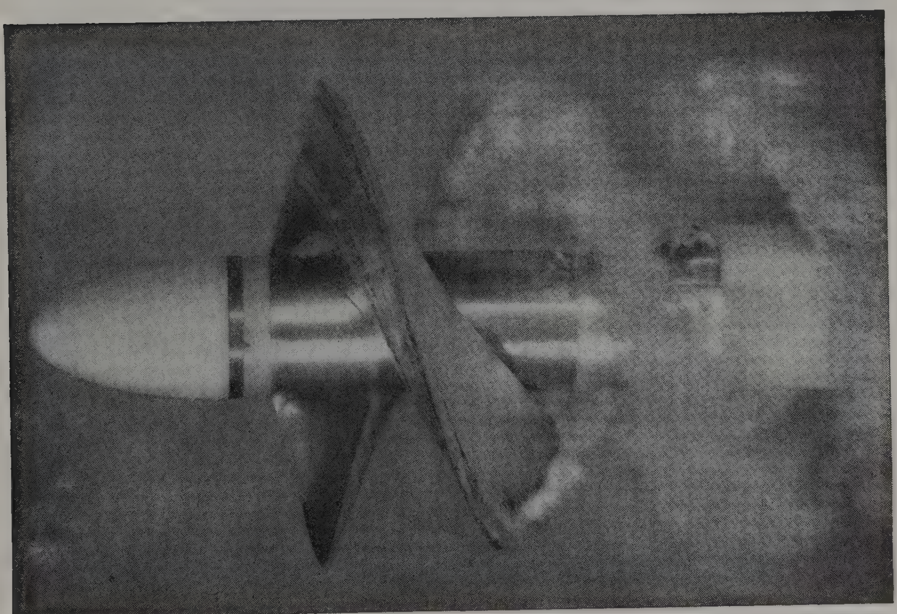


FIG. 4.4 A NEW PROPELLER DEVELOPED BY THE NAVY'S BUREAU OF SHIPS AND THE OFFICE OF NAVAL RESEARCH. IT IS KNOWN AS THE "SUPERCAVITATING PROPELLER." NOTE THE NEW PROFILE, RESEMBLING THE SPIRAL OF A BIT. *Official U.S. Navy Photograph*

that stream behind the blades and consume much energy. The supercavitating propeller, operating at high speed, thus eliminating reduction gears in some installations, creates a vapor cavity along the trailing edge of the new blade that results in a minimum of power loss.

FIG. 4.5 A CONVENTIONAL BLADED PROPELLER AS IT REVOLVES. NOTE THE TURBULENCE OR CAVITATION WHICH LIMITS ITS SPEED AND EFFICIENCY AND HOW IT COMPARES WITH FIG. 4.4. *Official U.S. Navy Photograph*

4.13. Steering. Steering implies the ability to hold a course, and for this there must be an adequate combination of fixed or movable stern control surfaces (skigs or rudders respectively). For turning, the rudder is of major importance with some complex interactions with skigs or other fixed structure.

The usual method of changing the heading of a ship underway is by putting the rudder over to one side or the other. The action of the water on the rudder forces the stern of the vessel sideways, and the vessel changes course. Until saturation of rudder area is reached, the larger the rudder, the tighter the ship will turn, because there is a larger area on which the water can act.

Besides the area of the rudder, the speed of the water past the rudder also affects the response of a ship to putting the rudder over; the faster the water is traveling, the better the response. Because the water is traveling faster directly astern of the propellers, rudders directly abaft the propellers permit

getting rudder forces at zero and low speeds. We can see then that if a ship is to be very maneuverable and have a small turning circle, the rudder should be as large as possible or two rudders should be provided, preferably abaft propellers.

Rudders are of three general types: balanced, semibalanced, and unbalanced, as shown in Fig. 4.6. When part of the rudder area is located forward of the rudder stock, the rudder is easier to turn because the action of the water on that

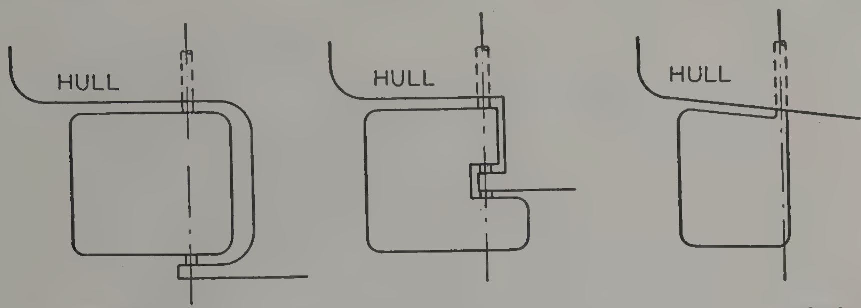


FIG. 4.6 COMMON TYPES OF RUDDERS

part tends to help the rudder turn. The unbalanced rudder is the hardest to turn. The choice of rudder is determined by the shape of a vessel's stern, the number of propellers, and the speed the vessel will develop. To turn the rudder a steering gear is required.

4.14. The Steering Engines. The electrohydraulic type of steering gear (Fig. 4.7) is used on all modern naval ships. The hydraulic power is furnished by a variable stroke hydraulic pump driven by a continuously running

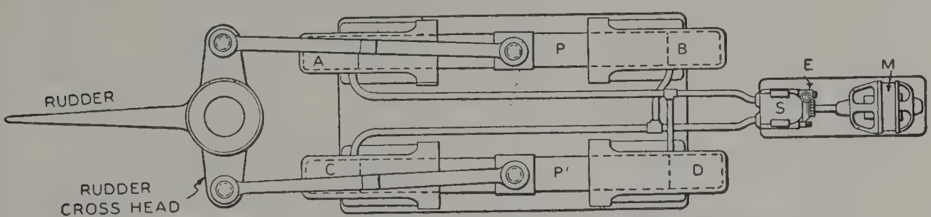


FIG. 4.7 DIAGRAMMATIC PLAN OF ELECTROHYDRAULIC STEERING ENGINE

constant-speed electric motor. There are many variations of the number and arrangement of the hydraulic rams, pumps, and driving motors, and of the method of transmitting the motion of the rams to the rudder cross-head, but the schematic drawing shown in Fig. 4.7 illustrates the essential principles of this type of steering gear. As shown in this plan, movement of the control mechanism E in one direction causes the pump S to take suction from one pipe leading to it and put pressure on the other. Movement of the control

mechanism in the opposite direction causes the direction of pumping to be reversed. When the control mechanism is in the neutral position, a hydraulic lock is placed on the rams, and no fluid is pumped. The rate of pumping in either direction depends on the amount of movement of the control mechanism which is constructed so that a small movement will produce the maximum available rate.

The electrical self-synchronous type of control is used by all modern naval ships. Briefly, the system consists of a synchro transmitter controlled by the motion of the steering wheel, suitable electric leads, and a synchro receiver connected to the control mechanism at the steering gear. Synchro transmitters and receivers are alternating-current electric motors designed so that the rotor of the receiver follows, in speed and amount of angular displacement, the motion of the transmitter rotor. Motion of the steering wheel, which is carried on an extension of the shaft of the synchro transmitter rotor, is, therefore, transmitted directly to the control mechanism which acts to cause the steering gear to produce the desired rudder angle.

With all types of steering gear control, provision is made on all naval ships and on most other ships for quickly shifting control from station to station. The practice of making this shift of steering control part of the daily routine offers valuable training for handling a casualty in any ship control station.

When twin rudders are provided, they both turn the same amount in the same direction if steering control is on the bridge. However, on some ships, when control is shifted to the steering engine room (some large ships have separate steering engines for each rudder), each room can independently control the motion of its own rudder. In a ship where this is true, the old adage that a ship has no brake is proved false. While the design was not made expressly to permit this, both the rudders can be turned outward, thus slowing the ship just as landing flaps slow an airplane. Even though it is not recommended that officers of the deck make a practice of slowing down by using the rudders in this manner, and it involves using sound-powered telephones to give orders to the steering engine room, the OOD should know if such a method of slowing is available in his ship for use in unusual situations. For example, a ship may have way on and power to the steering engines but cannot back down. Fish-tailing the rudder or rudders together may also be an effective way of reducing ahead reach in a crash-back situation. This essentially introduces hull yaw as a braking device.

New devices for steering now being used are a variety of rudder and propeller mechanisms that give certain ships improved handling qualities. Some ships have an active rudder that has a small propeller with its own power source installed with it as an integral unit. Another example (Fig. 4.8) is a tug whose improved steering control, particularly when backing, is due to its Kort nozzle or shrouded propeller. Typical installations have a steering rudder abaft the propeller and a pair of flanking rudders forward of the propeller. The

steering rudder is used in the usual manner for ahead operation. The flanking rudders are for operating astern, and generally hard-over angles are used.

Another common device is the bow thruster unit. This can be a propeller in a fixed transverse tunnel at the bow, or a retractable, swiveling propeller unit, or a cycloidal type unit. Bow thrusters are primarily used as maneuvering assist devices in low speed operation.

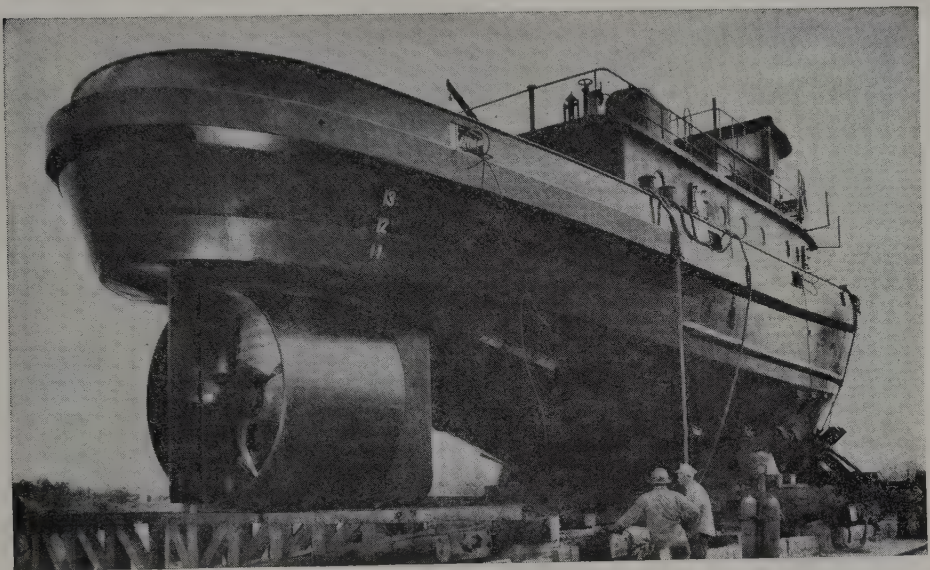


FIG. 4.8 THE DRAVO PIONEER, a tug fitted with the KORT nozzle or shrouded propeller.

5

Navigation

Navigation over the centuries has been the principal tool for assisting seamen in safely conducting ships to their destinations. The first fundamental navigational problem to be solved was that of direction. Very early in his history man discovered that directions at sea could be easily determined by reference to the stars, especially Polaris, and by reference to the sun when it rises, sets, or is at its greatest altitude. By the year 1100 A.D. the magnetic compass had been developed by the Arabs, permitting constant determination of direction regardless of weather.

The solution of latitude followed closely behind that of direction. Latitude is relatively easy to determine from the altitude of Polaris or from the greatest daily altitude of the sun (local apparent noon). We find then that up until the middle of the eighteenth century the only practical method of going from one point to a more distant one was to sail with the wind to the latitude of the destination and then to tack across along the latitude circle until the opposite shore was reached. Because of instrumental inaccuracies (sextants then could only read to one-half degree) there was much beating up and down the coast to find the final destination.

The determination of longitude at sea was the most difficult problem of navigation but this was solved in 1734 when John Harrison, an Englishman, invented the first successful chronometer. With the ability to know accurate time at sea, the three fundamental problems of navigation were finally solved: determination of direction, latitude, and longitude.

Hadley in England and Godfrey in America invented the marine sextant in 1731. Thomas Sumner discovered in 1837 that a single altitude observation of a celestial body could be used to compute a line of position upon which the observer must lie. Since then there were additional developments in techniques, and especially in instrumentation, but very few changes in principles. Up until the beginning of World War II, standard navigation equipment consisted of magnetic and gyro compasses for course determination, alidades and radio direction finders for azimuth and bearing, pitometer logs for speed *through the water* (speed over the ground is still very difficult to determine), stadimeters and range finders for distance measurements, echo sounders for measuring depth of water, and, of course, chronometers, radio time signals, and sextants for celestial determination of latitude and longitude.

With World War II came the development of radar and electronic position-

ing systems such as LORAN, SHORAN, and DECCA which enabled navigators to obtain an accurate fix at great distances from shore, regardless of cloud cover. This provided a considerable advantage because celestial observations are normally restricted to star observations at sunrise and sunset, with sun lines during the day. In the event of overcast, a ship might not be able to fix its position celestially perhaps for weeks at a time.

During the decade immediately following the end of World War II celestial and electronic equipment were adequate for merchant marine and naval navigation. However, with the arrival of satellites, intercontinental missiles, deep diving nuclear submarines, and other sophisticated military weapon systems, there came a requirement for new navigational techniques with unprecedented accuracy.

It was found, for instance, that our knowledge of the size and shape of the earth was inadequate for military purposes. Electronic surveying with HIRAN showed that the Grand Bahama Islands were six miles out of their charted position with respect to the North American land mass. Long range ballistic missiles need continuous azimuth information over the course of their trajectory and this could only be obtained with new inertial navigation techniques.

The purpose of this chapter is to discuss briefly various types of navigation: piloting, dead reckoning, celestial, electronic, inertial, and satellite. These discussions will be followed by a short description of how to make a hydrographic survey in areas where existing charts are inadequate and of simple maneuvering board problems. For a detailed discussion of the computations, techniques, or procedures needed for navigation the reader should consult any of the special references listed in the bibliography. Table 5.1 summarizes the advantages, disadvantages, and characteristics of the various methods of navigation presented in this chapter.

5.1. Piloting. The most important requirement for successful piloting is advance preparation. This presupposes, of course, complete familiarization with the techniques, instruments, publications, and procedures needed for piloting.

The navigator should familiarize himself with the area: location of shoals or other dangers, characteristics of lights, depths of channels, tide and current information, local laws for speeds in channels, restricted anchorage areas, requirements for having a pilot on board, and similar items.

Long before entering pilot waters, the navigator should make certain that all of the necessary charts, drafting instruments, and publications are readily available. Tide and current conditions should also be precomputed and available at the navigator's chart table.

It must be kept in mind that fixes in pilot waters should be taken every 10 minutes and in channels every 2 or 3 minutes. With such a schedule there is no time available to look for the next chart, or drafting instruments such as dividers, pencils, erasers, navigational slide rule, etc.

A helpful suggestion is to tack down on the plotting table each chart in the

TABLE 5.1. SUMMARY OF NAVIGATION TECHNIQUES

Technique	Range	Accuracy	Advantages	Disadvantages
Piloting	Line of sight (25 miles for ships)	±100 ft	Simple equipment; good accuracy; in general use; frequent fixes are possible	Dependent on good visibility
Dead reckoning	—	±10% of distance travelled since last fix	Simple equipment	Accuracy very limited
Celestial	—	±3 naut. miles	Can be used world wide; in general use	Affected by weather; only 2 fixes possible per day
Electronic LORAN A	700 N.M.	±3 N.M.	Frequent fixes; inexpensive equipment; easy to use; in general use	Affected by ionosphere; insufficient coverage; requires shore stations in foreign countries
LORAN C	1200 N.M.	±1 ft/N.M. from shore sta.	Frequent fixes; very accurate; easy to use; not affected by weather or ionosphere	Insufficient coverage; complicated equipment; requires shore stations in foreign countries
OMEGA	5000 N.M.	±1 N.M.	Frequent fixes; world wide coverage; inexpensive equipment	D.R. position must be known to ±10 N.M.; still under development
Inertial	10–12 hours	Depends on accuracy of reference fix and time since last fix: ±0.1 N.M. to ±3.0 N.M.	World wide coverage; constant indication of position; independent of weather	Complicated equipment; degrades in accuracy after a few hours; must be updated by fixes from another technique
Satellite	—	±0.1 N.M.	World wide coverage; 1 fix every 90 min; independent of weather	Complicated and expensive equipment; still under development
Sextant Horizontal angles	Line of sight	±1 ft	Most accurate technique available	Depends on visibility; requires accurate shore stations; generally used only by experienced surveyors

* Based on information from article "Navigational Requirements for Oceanography" by Cdr. R. J. Alexander, page 164, *Journal of Institute of Navigation,* 1963, Vol. 10, No. 2.

reverse order that it will be required: the detailed harbor chart should be on the bottom because it will be the last one needed; on top of it should be the channel charts, followed by the harbor approach charts, with the coastal charts

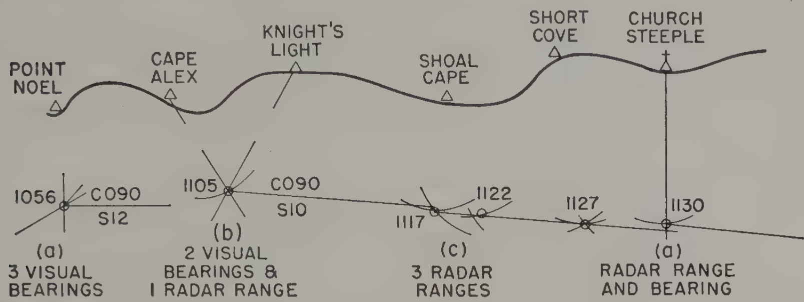


FIG. 5.1 TYPES OF PILOTING FIXES ALONG A WELL MARKED COAST

on the top of the pile. In this manner the navigator can plot his fixes on the first coastal chart until the next one is required. All that is necessary in shifting to another chart is to remove the finished chart and commence plotting on the next one which is already in place.

TIME	BEARING RANGE	BEARING RANGE	BEARING RANGE	REMARKS
	NOEL	ALEX	KNIGHT	
1056	000°T	035°T	042°T	C090, S 12KT
1100				PT NOEL NO LONGER VISIBLE
1105	—	330°T, 3200 YDS	030°T	CHANGED SPEED TO 10 KNOTS
1110				SHOAL CAPE NOT VISIBLE BUT SHOWS CLEARLY ON RADAR
1115	SHOAL	SHORT	CHURCH	REDUCED VISIBILITY SHIFT TO SHOAL, SHORT, AND CHURCH
1117	3400 YDS	6230 YDS	8040 YDS	
1122	3700 YDS	6000 YDS	7840 YDS	
1127	4230 YDS	5500 YDS	7720 YDS	
1129				CHURCH STEEPLE IS ONLY OBJECT IDENTIFIABLE ON RADAR
1130			000° T, 7500 YDS	PASSED STEEPLE ABEAM TO PORT

FIG. 5.2 METHOD OF RECORDING OBSERVATIONS

Another useful hint is always to use thumb tacks when placing a chart on the chart table. Transparent cellophane tape is an excellent adhesive but when

removed it ruins the chart. Ordinary masking tape is more suitable but should only be used on marginal edges of charts so that useful information will not be masked out or pulled off when the tape is removed.

Piloting fixes are obtained by simultaneous visual bearings, or one bearing and one range, or two ranges. The information is recorded in a bearing notebook immediately when observed and then plotted on the chart. Figure 5.1 shows the different types of fixes available and Fig. 5.2 shows the method of recording observations. Although only two simultaneous observations are needed to "fix" a ship's position, it is always desirable to take a third observation as a check.

5.2. Dead Reckoning. In the absence of techniques or equipment for constantly positioning a ship, the navigator must resort to dead reckoning (DR). For the most part, dead reckoning is used to determine the ship's position at any time after the last fix. However, hydrographic surveyors use dead reckoning techniques to reconstruct the track between fixes and naval courts of inquiry work backwards from a collision or grounding to determine the actual track made good during the period immediately prior to the accident.

The dead reckoning position is at best an approximate one which degrades in accuracy as the time increases since the last fix. For this reason all dead reckoning equipment must be corrected with the latest accurate fix information at varying intervals of time. On the high seas a DR plot can be maintained for several days with sufficient accuracy. In pilot waters, because of nearby dangers, the DR position would not be accurate enough after 10 minutes and in restricted channels after 2 or 3 minutes.

The most important information for any DR position is an accurate knowledge of the course and speed made good over the ground. This is difficult to obtain from shipboard. Currents vary in speed and direction, the best helmsmen wander from the prescribed course, compasses themselves have varying errors, and speed indicators such as engine revolution indicators or pit logs can only provide information on speed through the water.

Navigators take great care in arriving at a DR position but there are so many uncertainties in our knowledge of the effects of winds, tides, current, and instrumental errors that DR information is only used when it is not possible or convenient to take a fix. Figure 5.3 shows a typical dead reckoning plot where compass course and engine revolutions are assumed to give course and speed over the water. No consideration is given in the figure to the other variables mentioned above.

There are a number of devices available for performing all or part of DR operations. They vary from the simple course recorder which gives a graphical record of the courses steered through very sophisticated inertial systems. The usual equipment found on larger ships receives electrical-mechanical inputs from the gyro compass and pit log. These inputs are used to compute changes in latitude and longitude by the departure method used in old-time sailing navigation. Latitude and longitude are set in from the latest fix information

and as the ship proceeds the changes are mechanically added or subtracted to the original position to give a continuous DR position of latitude and longitude. A graphical plot can be obtained by providing the equipment with a pen or pencil to move across a plotting sheet.

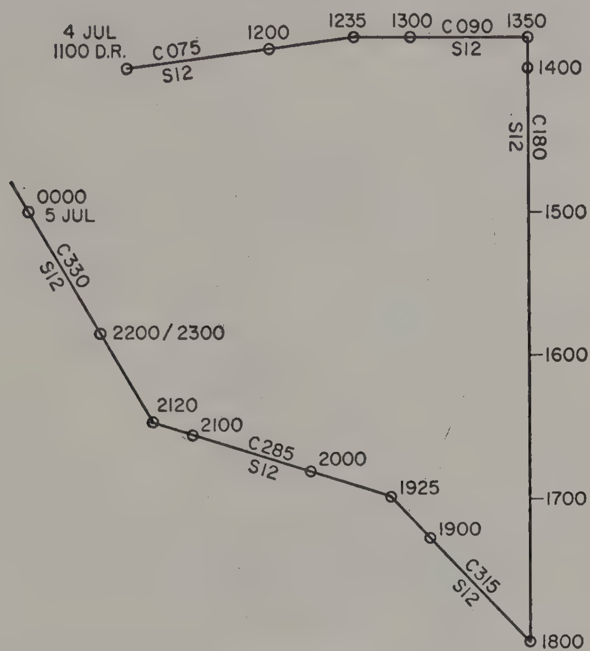


FIG. 5.3 TYPICAL DEAD RECKONING PLOT. Plot commenced at 1100 4 Jul on course 075° True, speed 12 knots. At 1235 course was changed to 090° T, at 1350 to 180° T, at 1800 to 315° T, at 1925 to 285° T, and at 2120 to 330° T. Note time advanced 1 hour at 2200 to conform with new time zone.

5.3. Celestial Navigation. The stars change their position with respect to an observer from second to second during the night and from day to day with respect to the sun. Despite this apparently complicated movement, the stars do move with predictable regularity so that their position at any instant with respect to an observer can be easily determined from the Nautical Almanac, Air Almanac, or similar astronomical publication.

The task of celestial navigation is to solve the spherical triangle formed by the observer's zenith, the pole, and the star. By observing the star's altitude, recording the time of observation, and obtaining hour angle, right ascension, and declination from an almanac the navigator can solve for the missing elements of the triangle as illustrated in Fig. 5.4.

The direct solution of the triangle involves such tedious time consuming computations that for practical purposes it is easier to use indirect methods.

The navigator uses an assumed position close to his dead reckoning position so as to reduce tabular interpolations and then computes what the altitude of the body should be when viewed from the assumed position.

By comparing the observed altitude with the computed altitude and by using the computed azimuth a line of position can be plotted. The line of position is actually an arc of a circle but for short distances can be treated as a straight line. Figure 5.5 illustrates the principles described above.

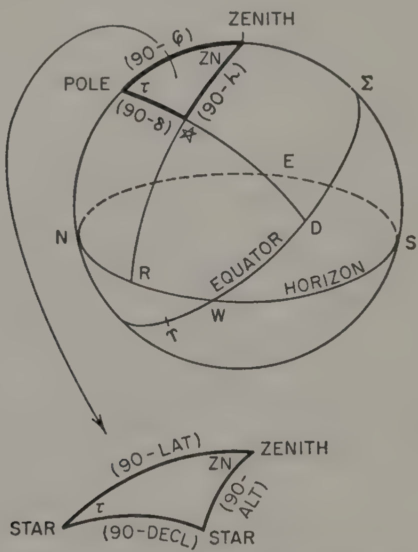


FIG. 5.4 THE CELESTIAL TRIANGLE. The earth is at the center of the celestial sphere. Along the horizon circle NESW are the four cardinal directions north through west. The celestial triangle is formed by the pole, zenith, and star (see inset). Along the equator from ϒ to D is right ascension (R.A.); the distance D☆ is the declination. Both of these values for a particular star are taken from Nautical Almanac. NESWR measured along the horizon is star's azimuth. R☆ is star's observed altitude. N-pole is altitude of pole which equals the observer's latitude. t is hour angle of star. If any of the three elements of the celestial triangle are known, the other elements can be computed by spherical trigonometry.

Tabular methods where computed altitude and azimuth can be obtained by directly entering special tables with latitude, declination, and hour angle as arguments are the methods most commonly used today and are employed in conjunction with special tables such as H.O. 211 and H.O. 214, published by the Oceanographic Office.

Aside from using precision instruments with accurate tables and almanacs, one of the prime requirements for good celestial navigation is to have an exact knowledge of time. Before World War II this was generally obtained by having three extremely accurate chronometers on board. By daily comparison with radio time signals (when available) or by comparing the rates of all three chronometers it was possible to keep time accurate to two or three seconds.

It was always necessary to have three chronometers, however, because if one chronometer should develop an unexpected error, in the absence of radio time signals, it could only be detected by the fact that two other chronometers were in agreement.

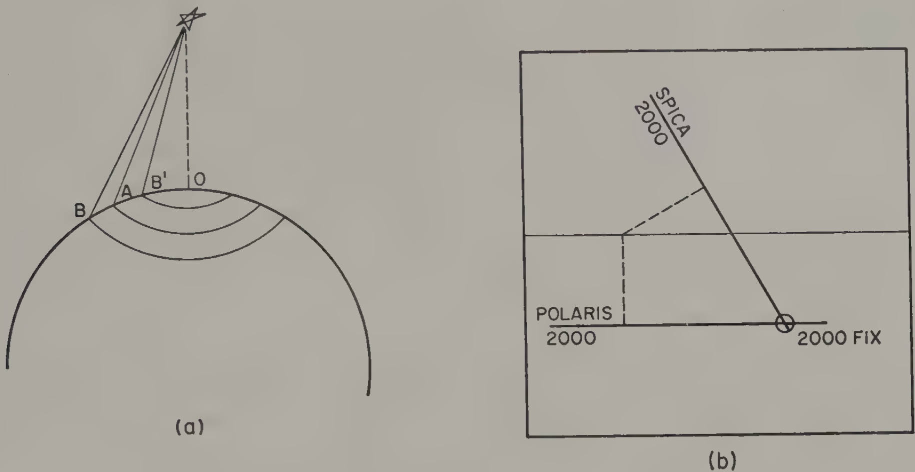


FIG. 5.5 PLOTTING A CELESTIAL LINE OF POSITION

(a) O is the star's substellar point; A is the assumed ship's position from which can be determined the altitude star would have if observer were at point A. This computed altitude is h_c. B is the actual position corresponding with the observed altitude h_o. If h_c is greater than h_o then intercept AB is drawn in direction of the reciprocal of the computed azimuth. If h_c is less than h_o then intercept AB′ is drawn in direction of computed azimuth.

(b)

	Polaris		Spica
h_c	50 05′.0	h_c	42 36′.0
h_o	50 00 .0	h_o	42 40 .0
	5′.0 away		4′.0 toward
	Computed azimuth 000		Computed azimuth 045

At 2000 local time, simultaneous observations were made of Spica and Polaris with results shown. For Polaris a distance 5.0 nautical miles (5′.0) is laid off along the *reciprocal* of the computed azimuth and a line of position laid off perpendicular to this point. For Spica a distance of 4.0 nautical miles is laid off in direction of the computed azimuth and a line of position constructed perpendicular to it. The intersection of the two lines of position is the 2000 fix.

Since World War II a world-wide net of radio stations has been established to provide navigators with time signals on a constant 24-hour basis. This has drastically reduced the need for chronometers. It is now possible to obtain a radio time signal a few hours before observations and by setting a good comparing watch to the time signal still have very accurate time for observations. A full discussion of the various time signals available throughout the world is given in H.O. Pub. 117.

A word of caution should be given about the accuracy of celestial navigation.

There are errors in all navigational systems but in celestial work errors can creep in which are difficult, if not impossible, to detect. The gravest error is caused by refraction. Storms, fog, changes in humidity, and a variety of other factors affect refraction long after adverse conditions have apparently cleared. In an open sea with not a cloud visible there may be enough refraction from the remnants of a storm which has passed to introduce errors of five or ten miles in position.

Many navigators, either for amusement or in the mistaken idea that they are achieving increased accuracy, take and work out observations on five or more stars. If the lines of position one day do happen to cross in a point, the navigator points with pride and says "Captain, this is our *exact* position." Nothing could be further from the truth. Regardless of the number of lines of position that cross in a point, there are so many random and systematic errors affecting the observations at sea that it is unlikely that the ship would be within two miles of the intersection point.

5.4. Electronic Navigation. Of all forms of navigation the most spectacular progress has been made in electronic navigation. The electronic industry stems from the development in 1864 of James Clerk Maxwell's theory of wave travel. In 1883 Heinrich Hertz made two fundamental discoveries based on Maxwell's laws which are the foundations of radar and electronic positioning systems:

1. Radio waves are reflected by obstructions, and
2. Reflected radio waves obey laws of reflection, refraction, and propagation very similar to the optical laws governing light rays.

In 1936 the U.S. Army developed the first pulse type radar system which was followed one year later by the first shipborne radar trials. In 1942 the development of the magnetron permitted the use of very high frequency waves (known as micro waves) for radar. During World War II there was a critical military need for long range navigation systems which resulted in the development of LORAN by the U.S. for ship navigation out to 500 miles and of GEE by the British for aircraft bombing navigation out to 300 miles. Since then many new improvements have been devised so that today there is a wide variety of electronic systems available for all types of navigation. Table 5.2 contains the characteristics of the systems currently in use or under development, ranging from short range extremely accurate systems for harbor surveys through long range, world wide systems for navigation on the high seas.

Electronic positioning systems are classified in several ways:

1. Type of lines of position. If position is determined by measuring the round trip travel time from the ship's transmitter-receiver to a fixed shore station a family of concentric circular lines of position is set up with the fixed shore station as center. Radar ranges and SHORAN-HIRAN are examples of circular types of lines of position. Circular systems, also called ranging or distance measurements, require transmission by the user which seriously limits

TABLE 5.2. CHARACTERISTICS OF ELECTRONIC SYSTEMS IN GENERAL USE

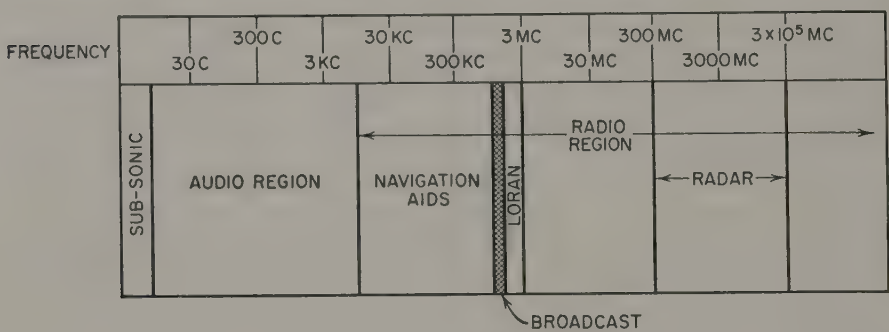
System	Range	Accuracy	Type of Lines of Position	Type of Transmission	Type of Time Measurement	Frequency	Remarks
CONSOL	700 N.M.	½° to 2½°	Hyperbolic	Continuous wave	—	250–400 kilocycles	Provides bearing info only
DECCA	250 N.M.	±1 N.M. (routine use) ±100 ft (survey use)	Hyperbolic	Continuous wave	Phase comparison	85–127.5 K.C.	Available for general navigation and also for special survey needs
E.P.I.	480 N.M.	±¼ N.M.	Circular	Pulse	Equalized and superimposed pulses	1850 K.C.	Survey use only
GEE	400 N.M.	±3 N.M.	Hyperbolic	Pulse	—	20–80 megacycles	A World War II development
HIRAN	400 N.M.	±10 ft	Circular	Pulse	Superimposed pulses	225–330 M.C.	Modified SHORAN for aircraft geodetic use only
LORAC	250 N.M.	±15 ft	Hyperbolic	Continuous wave	Phase comparison	1600–2500 K.C.	Survey use only
LORAN A	750 N.M. (ground wave) 1400 N.M. (sky wave)	±3 N.M. ±10 N.M.	Hyperbolic	Pulse	Equalized and superimposed pulses	1750–1950 K.C.	Widely used by American ships
LORAN C	1200 N.M.	±1 ft for each mile from shore station	Hyperbolic	Pulse	Matching phase within envelop	100 K.C.	Used for both survey and routine navigational use
OMEGA	5000 N.M.	±1 N.M.	Hyperbolic	Continuous wave	Pulse matching	10–14 K.C.	Under development
RAYDIST	250 N.M.	±12 ft	Hyperbolic	Continuous wave	Phase comparison	1600–3300 K.C.	Survey use only
SHORAN	25 N.M.	±50 ft	Circular	Pulse	Distance between pulses	225–330 megacycles	Limited number of uses on time sharing basis because of shipboard transmissions

the number of users and complicates military operations where radio (electronic) silence is essential.

If position is determined by measuring the time or phase difference from two synchronized transmitting shore stations, a family of hyperbolic lines of position is established with the transmitting stations as foci. LORAN and DECCA are examples of hyperbolic systems.

In either system the intersection of two or more lines of position determines the ship's position. Hyperbolic systems have the advantages of: longer ranges due to the lower frequencies employed; extremely simple shipboard equipment; and since there is no shipboard transmission, an unlimited number of observers may use the equipment at the same time without breaking electronic silence.

2. Type of transmission. In transmitting radio waves either pulse (intermittent wave) or continuous wave forms may be employed. Pulse power is by



Band	Abbreviation	Range of Frequency	Range of Wave Length
Audio	AF	20–20,000 cycles per sec.	15 million to 15,000 meters
Radio	RF	10 kc–300,000 mc	30,000 meters to 0.1 cm
Very low freq	VLF	10–30 kc	30,000–10,000 meters
Low freq	LF	30–300 kc	10,000–1000 meters
Medium freq	MF	300–3000 kc	1000–100 meters
High freq	HF	3–30 mc	100–10 meters
Very high freq	VHF	30–300 mc	10–1 meter
Ultra high fr	UHF	300–3000 mc	100–10 cm
Super high fr	SHF	3000–30,000 mc	10–1 cm
Extremely high freq	EHF	30,000–300,000 mc	1–0.1 cm
Heat and infrared		10^6–3.9×10^8 mc	.03–7.6×10^{-5} cm
Visible spectrum		3.9×10^8–7.9×10^8 mc	7.6×10^{-5}–3.8×10^{-5} cm
Ultra violet		7.9×10^8–2.3×10^{10} mc	3.8×10^{-5}–1.3×10^{-6} cm
X-rays		2.0×10^9–3.0×10^{13} mc	1.5×10^{-5}–1.0×10^{-9} cm
Gamma rays		2.3×10^{12}–3.0×10^{14} mc	1.3×10^{-8}–1.0×10^{-10} cm
Cosmic rays		Greater than 4.8×10^{15} mc	Less than 6.2×10^{-12} cm

FIG. 5.6 THE ELECTROMAGNETIC SPECTRUM

far the more economical since it requires much less power. In addition the direct wave traveling along the surface of the earth (ground wave) may be resolved without interference from the reflected wave bounced back from the ionosphere (sky wave). Pulsed systems can generally be worked in atmospheric conditions where continuous wave systems would break down but they are somewhat less accurate than continuous wave systems. LORAN is an example of a pulsed system which is widely used for navigation.

3. Type of Time Measurement. Measurement of the time between the reception of two simultaneous pulses from a master and slave network is done by measuring the distance between the pulses. This is usually accomplished by turning a vernier knob which will move one pulse over the other. When the pulses are superimposed the vernier reading will indicate the distance moved.

Measurement of phase consists in measuring the phase angle difference between two radio waves. It is the most accurate of all techniques but is employed most often with continuous wave systems used in precise hydrographic surveys of harbors and channels.

4. Type of frequencies. The choice of frequency used in any system is a very important consideration because frequency dictates size, range, accuracy, and other characteristics of the equipment. The assignment of a specific frequency for navigational purposes is done on an international basis to prevent interference with frequencies allotted to other purposes. Figure 5.6 gives a general idea of how the electromagnetic frequency spectrum is divided.

High frequencies (short waves) are characterized by smaller antennas; increased accuracy; line of sight range; less interference from sky waves; and

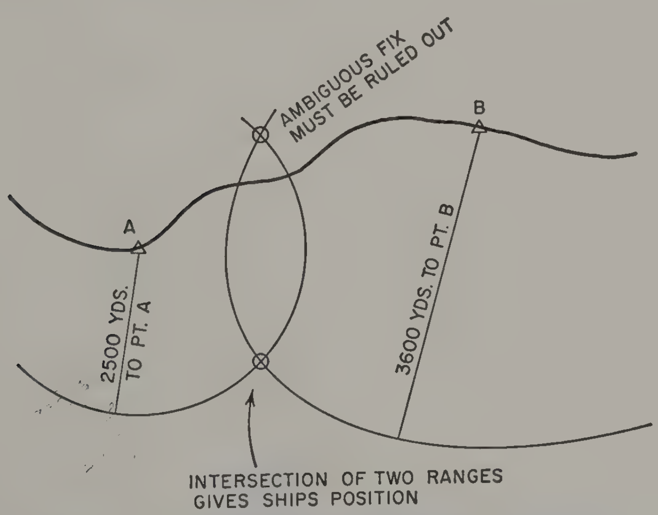


FIG. 5.7 POSITIONING BY CIRCULAR LINES OF POSITION

increased interference from very small objects such as raindrops, which will reflect or scatter very short waves.

Low frequencies (long waves) are characterized by larger and more expensive antenna systems; less accuracy; longer ranges by using ground wave transmission capable of circling the earth; sky wave interference; and greater interference from lightning or magnetic storms. OMEGA, a low frequency system presently under development, will provide world-wide coverage by 1970.

Figures 5.7 and 5.8 illustrate the principles of fixing the ship's position by circular and hyperbolic systems. These should be used in conjunction with

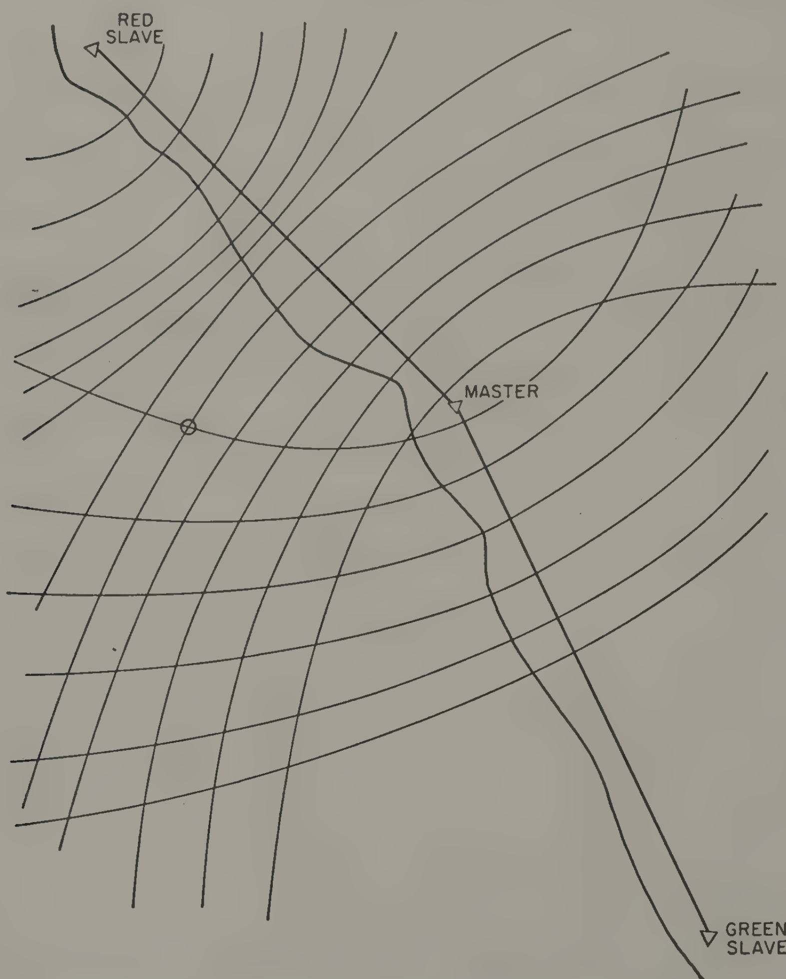


FIG. 5.8 POSITIONING BY HYPERBOLIC LINES OF POSITION. A line of constant time or phase difference defines a hyperbolic line of position. The intersection of two such lines of position determines the ship's position.

Table 5.2 which summarizes the characteristics of various electronic navigation systems.

5.5. Inertial Navigation. As a result of guidance systems developed for various missile systems, a number of inertial systems are now in use for shipboard navigation. Although these expensive and sophisticated systems are currently only available for selected fleet units, they will undoubtedly, within a few years, become inexpensive enough to become standard items of equipment on larger merchant marine and fleet units.

Inertial navigation is based on two principles: a body at rest will remain at rest or if in motion will remain in motion unless acted upon by an outside force; and every change in motion is accompanied by an acceleration. By measuring the forces which act to change a body's motion and by measuring a body's acceleration it is possible to determine the distance and direction traveled, which can easily be converted into position.

Inertial systems are closely related to dead reckoning. They are also concerned with some of the principles of celestial navigation since they are referenced to inertial space which is the same space through which the stars, sun, moon, and other celestial bodies move. Inertial position is obtained by measuring the components of a ship's acceleration in the east-west and north-south directions, integrating them once with respect to time to get velocity and then integrating them again to get distance. The distance is added to the latitude and longitude of the beginning point (or last fix) to give position.

Each inertial system would consist of the following basic building blocks (Fig. 5.9):

a. Two accelerometers placed at right angles to each other to measure the east-west and north-south components of a ship's motion. These accelerometers are mounted on an accelerometer table. This table, for reasons to be discussed later, must always be kept in a level (horizontal) position.

b. Three gyroscopes to detect the torques put on the system by the roll, pitch, and yaw motions of the ship.

c. A computer which receives electrical inputs from the gyroscopes and the accelerometers, analyzes the information, and then sends electrical signals to servo motors to bring the accelerometer table into proper level and to latitude-longitude counters for a continuous indication of position.

d. A precise clock to furnish time information to the computer.

None of the above components is new to navigation. Gyros, accelerometers, servo motors, and clocks have been used for years in such shipboard equipment as automatic steering, gyro compasses, fire control instruments, and ship stabilizers. The difficulty in the past in constructing an accurate inertial system was the extremely precise design specifications required of the components in the system. For example 1° of gyro drift per hour produces a 60-mile position error per hour. To meet the accuracy requirements of long-range missiles, inertial system gyros need a drift rate of less than .01° per hour.

To get an idea of how small such a drift rate is, it would take four years for an inertial gyro to make a complete revolution. The hour hand on a clock goes 3000 times faster than this. The most accurate gyroscopes at the end of World War II were those used in the Navy's fire control equipment.

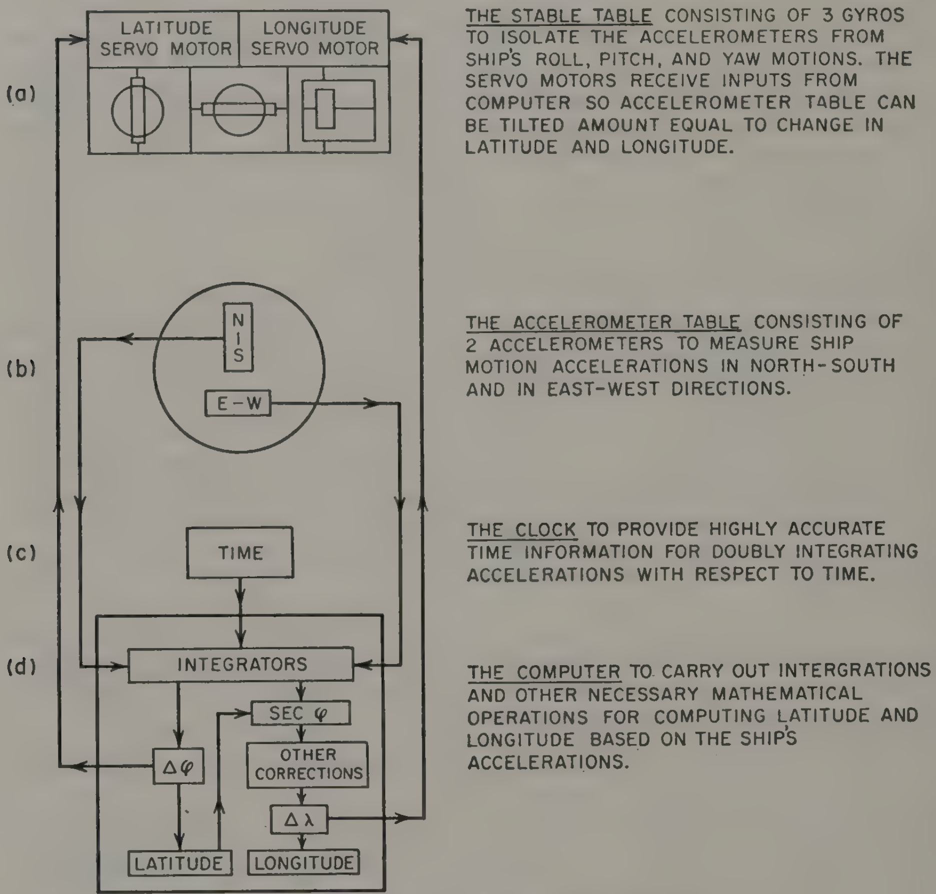


FIG. 5.9 SCHEMATIC OF AN INERTIAL SYSTEM

These gyros had a drift rate two or three times greater than the minimum acceptable for missile navigation and were, in addition, much too heavy.

By floating the gyros in heavy liquid it became possible to reduce the drift caused by bearing friction and this in turn reduced the size of the gyros. Bearing-less suspension, hermetic sealing, and other technological developments now permit manufacture of gyros capable of meeting the accuracy needs of inertial systems.

The requirements for precise accelerometers are even more severe than for

gyros. Missile accelerometers must be capable of measuring a range of accelerations which may vary as much as 100,000:1 with minimum values as low as .005 cm/sec^2. Of course shipboard accelerometers are not required to measure the wide range of accelerations that would occur in a missile.

In measuring accelerations we must remember that the accelerometer is an unthinking machine. It just measures accelerations regardless of type. It cannot distinguish between accelerations due to vehicle movement and those due to gravity. It is for this reason that the accelerometer table must always be level, or in other words kept perpendicular to the direction of gravity. To keep the accelerometers horizontal it is necessary to isolate them from the roll, pitch, and yaw motions of the ship by mounting them on a gyro stabilized table.

But to do this, it is first necessary at all times to know the direction of gravity, or, to use a different phrase, the direction of the vertical. In 1923 Dr. Maximilian Schuler developed the concept of the "earth pendulum" or Schuler principle, which made determination of the direction of the vertical possible. This led to development of the first practical inertial navigation systems.

The Schuler principle states that the direction of gravity (vertical) is determined by the direction a pendulum would take if it had a length equal to the radius of the earth. Such a pendulum would have a length of 4000 miles with a period of swing of 84 minutes.

It is obviously impossible to construct a pendulum with such a tremendous length, but it is relatively easy to insert an oscillatory motion into the accelerometer table so that it moves about the vertical with a natural period of 84 minutes. This oscillatory motion for all practical purposes simulates the earth pendulum and enables the system to seek out the true vertical for keeping the accelerometer horizontal.

In addition to solving the problem of separating gravity acceleration from ship motion acceleration, the Schuler principle helps reduce other errors which creep into the system. There are a number of residual instrumental errors which cannot be removed from the system. These include gyro drift, timing errors, accelerometer imbalance, and a host of other minute errors in the various component parts. Since the measured accelerations are integrated twice with respect to time to get distance, instrumental errors will build up as the square of time. The cumulative effect of this error buildup would result in an intolerable distance error within a few hours. By using the Schuler principle, runaway errors are constrained from building up in a T^2 ratio and instead are kept within predictable tolerances by forcing them to oscillate with an 84-minute period.

Besides the gravity accelerations there are several other spurious accelerations which affect the system. Coriolis effect, oblateness of the earth, speed of earth's rotation, and convergence of the meridians involve problems which are handled internally by the system's computer. The details of the computer

operations is beyond the scope of this chapter. It can be stated, however, that any problem which can be reduced to a mathematical equation can be solved by modern computers.

In summary, inertial navigation systems are of invaluable use for military navigators. These self-contained systems require no expensive shore stations, do not require the ship to send out electronic signals when electronic silence is

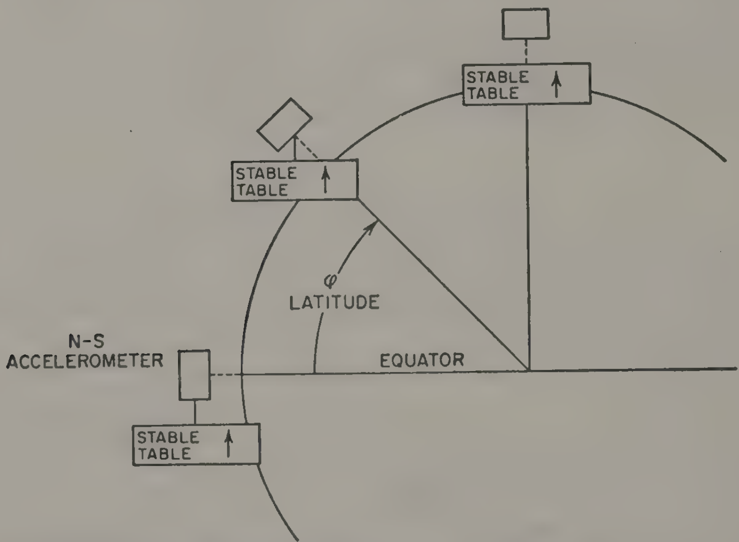


FIG. 5.10 RELATIONSHIPS OF INERTIAL COMPONENTS IN GOING FROM EQUATOR TO NORTH POLE. This figure shows that regardless of its position on the earth's surface, the axis of the stable table will always point in the same direction (North). It must also be noted that the accelerometers are always kept perpendicular to a line running through the center of the earth. This is what keeping the accelerometers level means. It is clear from the center position that the equatorial mount keeps the gyro carriages parallel to the earth's axis.

in force, and, being completely automatic, require no operator to be on watch. Their main advantage for all navigators, military as well as civil, is that they provide a continuous indication of position. Their only disadvantage is that they must be updated and corrected by positions obtained by other means. Therefore, it is not possible to navigate ONLY with inertial means.

Figure 5.10 illustrates the positions of the various components as a ship proceeds from the equator to the North Pole. It can be seen that the equatorial mount is rotated to keep the accelerometers level and perpendicular to the direction of gravity. The angular rotation of the accelerometer table corresponds to the ship's angular displacements in latitude and longitude. The gyroscopes, of course, retain their position with respect to space throughout the entire voyage so that their carriage is always parallel to the earth's axis.

As the ship proceeds the accelerometers continue their measurements with

their outputs simultaneously generating electrical signals which: a. tip and rotate the accelerometer table so as to keep it constantly level, and b. are integrated twice with respect to time and fed back into the latitude and longitude counters to give a continuous reading of the ship's position. Of course, because of instrumental errors the inertial position degrades with time and must be periodically corrected and updated with a fix taken celestially or electronically.

5.6. Satellite Navigation (Project Transit). In September 1959 the U.S. Navy commenced a series of experiments to place a navigation satellite in orbit about the earth. Although the system is still in the research and development stage it shows such excellent promise of being available by 1970 that a few words on its principles of operation should be made.

There is a universal need for a worldwide, all-weather, inexpensive, passive (requiring no signal from the user), accurate navigation system. The military have obvious uses for such a system as do the merchant marine, civil airlines, and other organizations requiring precise navigation.

Celestial navigation and visual piloting are severely hampered by cloud cover or fog; electronic navigation also is subjected to the effects of thunderstorms besides having rather less than worldwide coverage; inertial navigation, although worldwide in application, requires updating from other sources. The Transit Satellite System overcomes these difficulties and when developed will meet the needs of modern navigators in all areas of the world irrespective of weather.

The scientific principle of Project Transit is the Doppler shift phenomena. It has been found that if a sound source moves with respect to an observer there will be an apparent change in pitch (frequency). A common occurrence is the change in pitch of a train whistle as it approaches and then recedes from an observer. Although initially used in acoustic experiments, the Doppler principle has been found to apply to all types of electromagnetic radiation. The principle is used extensively in such navigation equipment as radio altimeters, Doppler radar, and Doppler sonar.

In essence the satellite transmits a continuous radio signal at a fixed frequency. The amount of the apparent change in frequency recorded by the observer or receiving station is proportional to the satellite's velocity of approach or recession. The frequency increases as the satellite approaches the observer, and decreases as it recedes. The amount of the shift depends on the position of the observing ship with respect to the satellite's position in its orbit.

By making very precise measurements of the frequency shift it is possible to determine the ship's relative position with respect to the satellite. From a knowledge of the satellite's position in its orbit it is then possible to convert the ship's relative position with respect to the satellite into a precise geographic position.

The accuracy in the Project Transit Satellite navigation system derives

from two factors: the two quantities of frequency and time can readily be measured to an accuracy of one point in a billion; and the satellite's possible orbits can be determined by solving the two-body problem of astronomy using Newton's laws of motion. For all of the orbits which are possible under Newton's laws, there is only one which will produce a particular curve of Doppler shift. By correlating the curve of observed frequency shift with the possible satellite orbits the ship's position with respect to the satellite is determined.

The system calls for four satellites in orbit at any one time which will guarantee navigational fixes anywhere on the earth at least once every 1½ hours. When four satellites are in orbit the system can maintain itself with one additional satellite launching every year. This additional satellite launching is needed to replace a dying satellite or to fill gaps in the coverage due to changes in orbits caused by precession of the satellites. Figures 5.11 and 5.12 show typical Transit orbits and a schematic sketch of how the System operates.

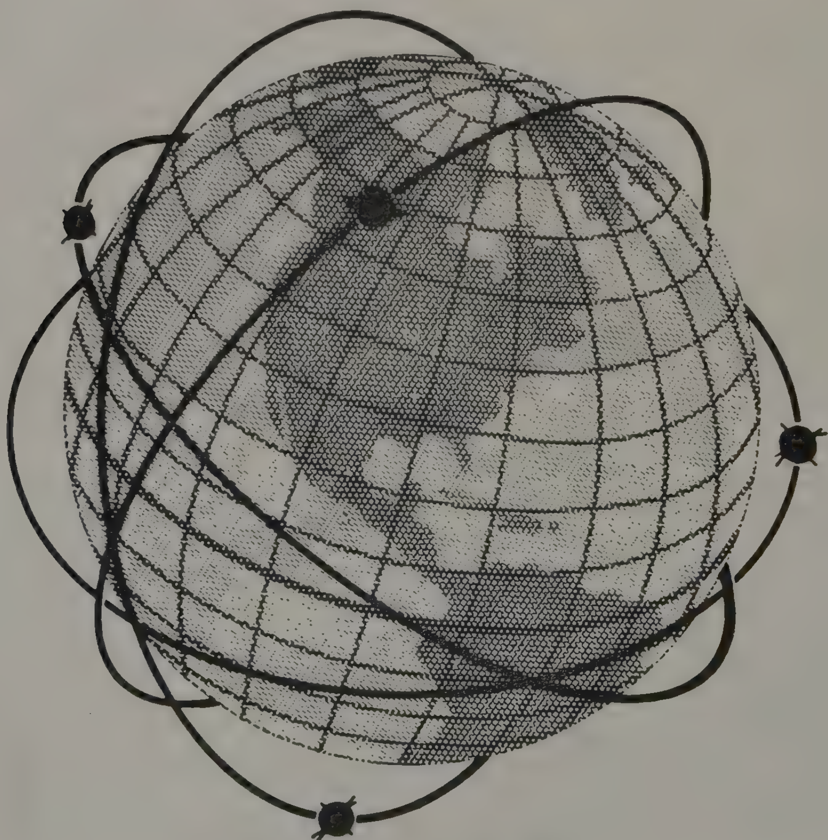


FIG. 5.11 TYPICAL TRANSIT ORBITS

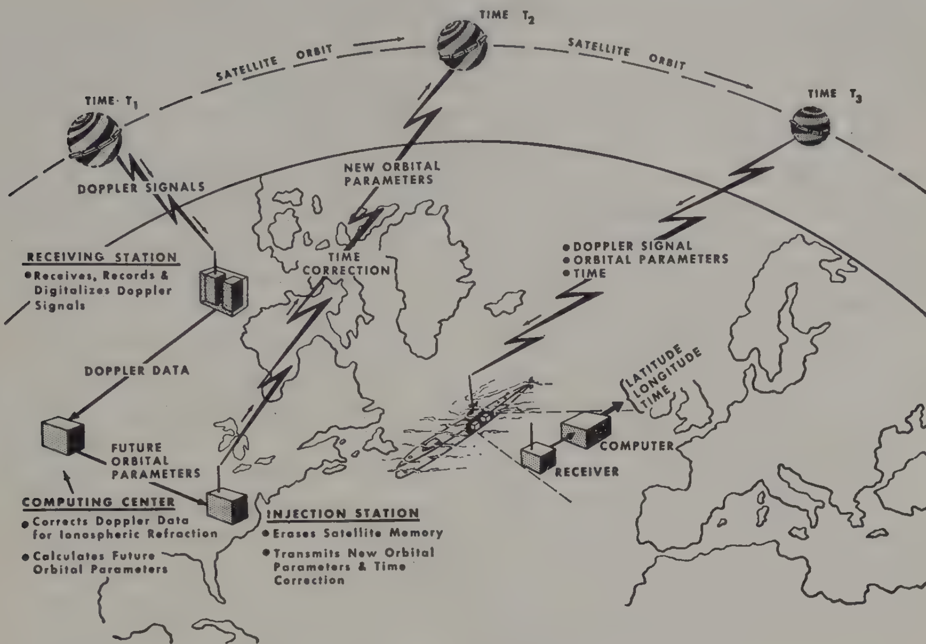


FIG. 5.12 SCHEMATIC SYSTEM OPERATION

There are two fundamental problems inherent in the Transit navigational system. For one thing, the ionosphere bends radio waves in a manner similar to the way atmospheric refraction bends light rays. Just as atmospheric refraction gives a false indication of a star's altitude, so ionospheric bending gives an erroneous position of the satellite. The second problem is concerned with the shape of the earth. If the earth were a perfect sphere the satellite orbit would be very easy to compute. The earth, however, is flattened at the poles and, in fact, is known to be pear shaped with the southern hemisphere having a larger "bulge" than the northern.

The first problem is overcome by having the satellite transmit on two or more frequencies, with each frequency being bent a different amount by the ionosphere. By comparing the Doppler signal for each of the transmitted frequencies it is possible to determine the refraction effect of the ionosphere and to make the necessary corrections to reduce the Doppler shift to standard *in vacuo* conditions.

The problem of the earth's shape is more difficult to resolve. Every bulge will produce a wriggle in the satellite orbit which must be compensated for. By measuring the Doppler shift at shore stations whose geodetic positions are accurately known, scientists are able to measure the size of the bulges. Then, knowing the shape of the earth, it is relatively easy to predict the satellite's orbit and its amount of precession with each succeeding revolution about the earth.

Although the above description does present a much simplified version of the system, in order to obtain precise navigation fixes it will be necessary for user ships to carry a considerable amount of very sophisticated equipment. The navigation equipment will consist of radio receivers for reception of the frequencies transmitted by the satellite, a refraction correction device for reducing the observation to standard vacuum conditions, a digital processing unit for converting the vacuum Doppler signal to a form suitable for computation, receiving and decoding equipment to receive and display the orbital information of the satellite, and a digital computer suitably programmed to determine latitude and longitude.

Hopefully, as technology improves between now and 1970, the shipboard equipment will become smaller and more compact. That is the usual trend of modern research and development. In any case navigation by satellite will be an accomplished fact within the next few years.

5.7. Automatic Navigation. As can be seen from the foregoing sections, navigational techniques have become more and more automated. Inertial navigation is entirely automatic and many of the other systems place heavy reliance on computers and other modern devices. Great strides have also been taken to automate the other navigational techniques as well.

There are a great variety of automatic devices presently available and used by ships or aircraft. It has been found that many navigational tasks can be processed by machines. This includes such fundamental tasks as plotting bearings, matching LORAN pulses, entering tables or curves to determine position, or actually recording latitude and longitude.

Aside from the DRT with which most navigators are familiar, systems have been developed for automatically tracking the sun, moon, or stars and feeding the signals into a computer so that position is automatically printed out. In this system the navigator's function is restricted to identifying the celestial object, pointing the telescope at the object, and pushing a switch to start the operation. As soon as the switch is turned on the machine takes over, keeps the telescope centered on the star, and prints out the ship's position.

The above system is used primarily for missile navigation but has found application in periscope navigation from a submerged submarine. There are also systems available for general electronic navigation which cost on the order of $125,000 but which are completely automatic. In these systems, digital computers receive the electronic signal directly from the shipboard receiver, process the signal, analyze the results, and type out a printed position at any time interval from one minute to one hour. Since everything is handled electronically from reception of the signal to the final typed print-out, human error has been removed.

Despite their relatively high initial cost, automatic navigation systems have enormous advantages for ship and aircraft navigators. They provide an almost continuous indication of ship's position, remove human error and hence give a more accurate fix, and, above all, free the navigator or officer

on watch to carry out other duties. Such systems are most valuable for hydrographic survey operations, missile-tracking ships, and other special military operations but they are also useful for merchant ships or aircraft where there is a shortage of officer navigators.

5.8. Preparation of a Nautical Chart. Within the United States Government, there are two agencies responsible for the production of nautical charts. The U.S. Naval Oceanographic Office provides world-wide coverage for coasts and harbors outside the territorial limits of the U.S. The U.S. Coast and Geodetic Survey provides coverage for U.S. waters.

It takes several years and much work from the inception of the desire to make a chart until the finished chart is printed and ready for issue. Diplomatic clearances to survey in a foreign country must be obtained by the State Department. Survey ships must be scheduled at least one year in advance so that special supplies and equipment can be ordered. Finally it is highly desirable that aerial photography missions be flown over the land area in the vicinity of the harbor prior to the arrival of the survey ships in the area.

While enroute to the area, the ship's officers study the aerial photos to determine where triangulation stations can best be located and also prepare detailed plans for carrying out the survey. An important part of the enroute voyage is devoted to training the various survey parties in their assigned missions.

Upon arrival in the area, the commanding officer pays official calls on local officials and then work commences. Helicopters make reconnaissance flights over the area to familiarize party chiefs with the terrain. The first item to be accomplished after the official calls and reconnaissance is the establishment of a network of triangulation stations ashore.

A baseline is measured to an accuracy of one part in one million to provide scale (distance) control for the network. An astronomical position (ASTRO) for one station is determined based on observations of several hundred stars over a period of several days. This serves as the origin of the survey. If a connection is to be made to another existing network, there is no need for the ASTRO. A precise azimuth observation is made to .01 seconds of arc to provide orientation control for the chart.

Once the basic triangulation network has been established, electronic navigation stations are located ashore and the ships and small boats commence running back and forth recording depths continuously. The lines are spaced at varying intervals ranging from 50 feet to 500 yards depending on depth of water.

While the ships and boats run soundings, shore parties are busy completing the triangulation network, measuring tides, determining elevations, and a myriad of other technical details. Although the amount of work that can be accomplished in any nine-month season depends on weather, type of terrain, nature of the bottom, and other factors, an average amount is one harbor plus 50 miles of coast line. This assumes a hydrographic survey group consisting

of three ships, ten small sounding boats, two helicopters, and several hundred sailors and surveyors.

Upon return to port the survey records and data are shipped to the home office for replotting, checking, double checking, and drafting into a finished product. Within two or three years after the ships have completed their work the final charts can be ready for issue to mariners.

The set of charts resulting from the survey will comprise one harbor chart, two or three approach charts, and a coastal chart. The entire cost of producing such a set of five charts will amount to $5 million, involving three ships, over 1000 people, and will have taken in excess of five years to complete.

It is obvious from the above that it is not possible to make an accurate chart without technically qualified personnel and very specialized equipment. There are, however, two ways in which mariners can update or improve charts which are based on old or insufficient data. Along coasts where there are not enough landmarks located on the chart, or in harbors where the soundings are in doubt, the mariner, with very little effort can correct his chart.

5.9. Plotting Landmarks Along Coasts. The key to this operation is to begin work before coming upon the unmarked coast and while a number of good navigational objects are still available. The navigator should take piloting fixes at frequent intervals from charted objects and simultaneously take bearings and/or radar ranges to as *many* objects ahead as may be visible. After three fixes from known objects with cuts to unknown ones, each of the uncharted objects will have three bearing lines and/or three ranges, the intersection of which locates the objects on the chart. As the known objects fade from view, the newly plotted landmarks are available for fixing the ship's position while cuts are made to other visible but uncharted objects further along the coast. By constantly working ahead it is possible to navigate accurately for hundreds of miles along unmarked coasts. While assigned to a survey ship enroute to the Persian Gulf, the author obtained good fixes while passing through the Straits of Bab el Mandeb and, by using the above techniques, was able to navigate safely almost 1000 miles along the uncharted southern coast of the Arabian peninsula. The method has also been successfully employed while operating in Baffin Bay along the Greenland and Labrador Coasts.

The advantages of this type of navigation are: 1. Updating or rough improvisation of a chart; and 2. The selection of courses to avoid the uncharted objects. A word of caution should be added, however. It is a system that is full of traps for all but the most experienced navigator. For instance: 1. It must be used in conjunction with the fathometer or lead line to avert submerged dangers. 2. The farthest objects to right or left of the ship's course must be used to ensure clear passage. 3. As darkness approaches, this method becomes even more dangerous with the substitution of radar bearings for visual bearings.

5.10. Improving Harbor Charts. Most major harbors have been adequately surveyed and their chart coverage is suitable for navigation. Occasionally, a

ship is required to enter a harbor which has been only sparsely sounded. Under these conditions it is best to enter the harbor with a pilot on board and with a small boat preceding the ship taking hand lead soundings. The boat can signal if the soundings shoal up to dangerous levels. Immediately after anchoring the small boat should sound the water circling the ship out to the swing permitted by the scope of the anchor chain let out.

After it has been determined that there is enough water in the immediate anchorage area, the small boat should attempt a systematic survey of the harbor using horizontal sextant angles to plot the boat's position. This is done by simultaneously measuring with two sextants a pair of angles subtended by three fixed objects ashore. One observer measures the angle between the left and center objects while the other measures the angle between the center and right objects.

The left and right angles are set on a three-arm protractor and the arms of the protractor made to pass through the fixed objects on the chart. The position of the small boat will be at the center of the protractor. A small opening, located at the center of the protractor, permits insertion of a sharp pencil point to mark the location of the fix on the chart.

5.11. Simple Maneuvering Board Problems. Admiralty courts have consistently held that the ship to starboard (showing a red running light) has the right of way. The burdened ship is required to keep clear while the "privileged vessel" must maintain course and speed. The details of the Rules of the Road are contained in other chapters in this book. There are certain simple graphical procedures, however, which if made in time will clearly indicate the course and speed of the other ship as well as the time, bearing, and range of the closest point of approach. This information is needed by the commanding officer to determine what course and speed changes are needed to keep clear of the privileged vessel and/or to avoid collision.

For ships without radar or similar ranging device, the best expedient is to take frequent true bearings of the other ship. If the bearings remain constant and do not change, the ships are on collision course. If the bearings change rapidly to the left or right the ships will pass ahead or astern of each other, depending on the direction of the bearing change. If the bearings change slowly, check bearings should be made on the bow and stern. If either of these remain steady, there is danger of such a close crossing that the bow or stern, as appropriate, may collide.

For ships equipped with radar, a plot can be maintained directly on the PPI scope, using a grease pencil and ruler. In addition, polar plotting diagrams can be constructed or requisitioned as radar plotting sheet (H.O. 4665 series) or maneuvering board (H.O. 2665-20). These plotting sheets should be used in conjunction with or in lieu of the radar plot.

As soon as another ship is detected on radar, a grease pencil mark should be placed over the radar echo and the time labeled. Pencil marks with time labels should be made every two minutes for about six minutes to track the

other ship. If the course and speed of both ships are constant, the tracking points will plot in a straight line called a relative movement line. By extending the relative movement line past the center of the scope, the navigator will see graphically the relative movement of both ships.

At any particular instant the other ship is somewhere in the relative movement line. If a perpendicular is dropped from the center of the scope to the relative movement line, the length of the perpendicular in terms of the distance scale of the radar scope will be the distance at which the two ships will be closest to each other. The direction of the perpendicular is the bearing that the other ship will have at the closest point of approach.

The time at which the two ships will be at their closest is obtained by stepping off time with a pair of dividers. If the ship had been tracked at two-minute intervals, stepping off the successive two-minute intervals along the relative movement line will provide the time of closest approach.

The course and speed of the other ship are found by laying off a line from the center of the scope in the direction of own ship's course. A suitable scale for speed should be selected for the corresponding ship's speed so that a vector will be produced (see Fig. 5.13). From the end of the own ship's course-speed vector a line is draw parallel to the relative movement line. This is called the relative movement vector.

The relative speed is determined from the plot, by arithmetic, using the formula:

$$\frac{\text{distance in miles along relative movement line}}{\text{time interval of plot in minutes}} \times 60 = \text{relative speed}$$

The length of the relative movement vector is determined by laying off the relative speed as determined above and using the same speed scale as for the own ship's course-speed vector. If the center of the scope is connected with a line to the end of the relative movement vector, the direction of the line will be the course of the other ship and the length of the line will be the speed of the other ship, using the same speed scale as for the other vectors.

It can be seen that maintaining a plot as described above will provide the commanding officer with valuable information concerning the other ship's movements and the relative movements of both ships. The navigator should make every effort to start his plot as soon as the other ship is detected.

It is much easier and safer to take corrective action when the ships are 15 miles apart than it is when the ships are 3 or 4 miles apart and a critical situation has developed. If two 12-knot ships are approaching each other on crossing but almost opposite courses, a relative speed approaching 24 knots prevails. Under such conditions a ship first detected at 15 miles will have closed to 5 miles in less than half an hour. For this reason the plot described above should be started as soon as the other ship is detected with corrective action being taken within 10 minutes of the initial detection.

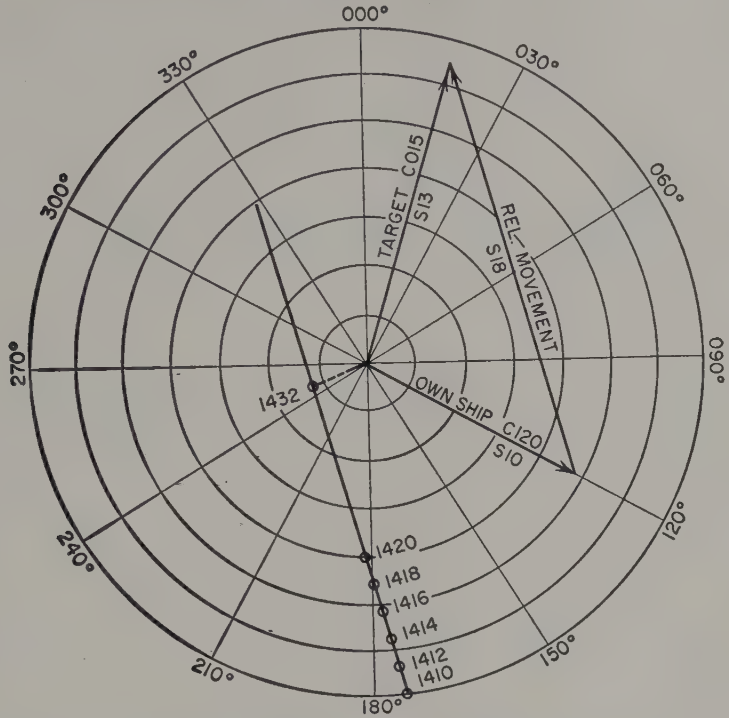


FIG. 5.13 TYPICAL RELATIVE MOVEMENT PLOT

Own ship on course 120° T, speed 10 knots, gets following radar ranges and bearings to target:

1410	175°, 14,000 yds
1412	172°, 13,000
1414	176°, 11,500
1416	178°, 10,400
1418	180°, 9,200
1420	182°, 8,000

Target's closest point of approach is at 1432, bearing 242, range 2500 yards.

$$\frac{3 \text{ miles}}{10 \text{ min}} \times 60 = 18 \text{ knots relative speed}$$

Target is on course 015, speed 13

A full discussion of navigational techniques and equipment is contained in the following references:

a. *American Practical Navigation,* Bowditch (H.O. 9), U.S. Navy Oceanographic Office, 1962
b. *Navigation and Piloting,* by Dutton, U.S. Naval Institute, 1962
c. *Practical Astronomy,* by J. J. Nassau, McGraw-Hill, 1945
d. Various issues of *Navigation, Journal of the Institute of Navigation,* Suite 700, 711 14th Street N.W., Washington, D.C.

6

Ship's Boats and Fishing Craft

Ship's Boats

6.1. Types and Uses. Boats are waterborne craft capable of limited independent operation. In most cases they are designed to be hoisted aboard ships. When assigned to Navy ships, boats are used for the routine tasks of transporting supplies and people. At sea, such boats serve as lifeboats, at least one being designated as the "ship's lifeboat." It is maintained in a ready condition at all times for rescue operations, for the training of the crew in man overboard drills, and for general boat training. Ship's boats are used as diving tenders, pusher tugs, or for depth-sounding purposes.

Landing craft are a special form of Naval boat used to transport troops, equipment, stores, fuel and ammunition between the ship and shore during landing operations. They are designed to land directly on the beach.

Many Naval boats are assigned to shore stations. For example: the *72-foot torpedo retriever,* used to recover submarine practice torpedoes; the *73-foot*

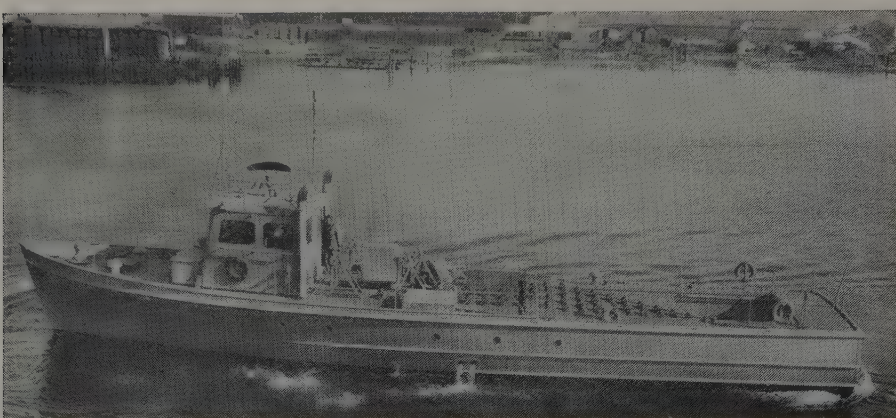


FIG. 6.1 72-FOOT TORPEDO RETRIEVER MK 2

noise measuring boat, used in connection with under-surface noise research. Others are *aviation rescue boats* (AVR), maintained in ready condition at air stations for rescue jobs; and *skimmers,* which remove oil from the surface of harbor waters.

6.2. Boat Construction. Metal, plastic and wood are the three materials used in building boats. Plastic is being used increasingly for boats under 50 feet in length, while metal or wood is used for the larger boats. Composite construction, wherein two or more materials are used, has proved generally unsatisfactory. Many boats designed for a given purpose have proved successful for other purposes. The 63-foot AVR (as converted) is used as a gunboat, patrol boat, noise measuring boat, personnel boat, and torpedo retriever—in addition to its original job of rescuing man from downed aircraft.

6.3. Materials. Marine plywood, plastic and glass cloth are important materials for pleasure boat construction. Wood is now seldom used for military craft, however. Some commercial boats are built of molded plywood, in which thin strips, impregnated with glue, are diagonally bent over a mold to the ship of the hull desired, building up a skin of several layers thickness. The mold is then placed in an autoclave where, at increased temperatures, the strips are curved and formed into a one-piece hull—which is light, strong, seamless and, as with all wood hulls, inherently buoyant.

With metal boats, the shell and frames are of welded sheet steel or of aluminum. Combinations of steel and aluminum are generally unsatisfactory for salt water service due to electrolytic action.

Plastic and glass boats now dominate current Navy construction in lengths of 50 feet and under. Such boats are built of layers of glass cloth laid in a

FIG. 6.2 39-FOOT ARCTIC SURVEY BOAT

mold of the desired shape for the final hull form. Each layer of cloth is impregnated with either epoxy or polyester resin and the completed hull permitted to dry before being removed from the mold. Plastic boats do not have seams. Those less than 26 feet in length generally use bulkheads for athwart-

ship stiffness rather than frames. Longitudinal strength is provided by plastic members built up inside the shell.

When built in quantity, the cost of plastic boats is comparable to that of wood or metal ones. Upkeep costs are generally less, though there are indications that minor repairs are needed more often. Plastic boats are impervious to ship worms. In contrast, they are quite susceptible to becoming fouled by marine organisms such as barnacles. These are difficult to remove on plastic hulls, for sand blasting cannot be done without damage to the hull. Therefore is it necessary that the antifouling bottom paint for such boats be renewed at regular intervals.

6.4. Buoyancy. Lifeboats and personnel boats, regardless of their construction material, are normally fitted with material or with air tanks to provide sufficient buoyancy to float the craft fully loaded. Styrofoam or cellular cellulose acetate (CCA) are the most popular forms of buoyant material used in wood or metal boats. This material is available in "plank" form and is customarily installed as near the sheer level as possible. In plastic boats it is normal practice to use foam.

In self-bailing boats a watertight deck runs the length of the boat slightly above the load waterline. The space below thus becomes a watertight compartment. Water from this deck runs overboard through freeing ports or scuppers in the side of the boat. Water that leaks into the compartments below the deck is pumped out by a bilge pump.

If the buoyancy of a boat can be carried high, above the waterline, the boat will tend to right itself if it should capsize. Self-righting boats are built in such a shape as to permit carrying the bow air tanks and stern air tanks high, and are also fitted with a heavy keel. Self-bailing and self-righting features are sometimes combined—as in the larger motor lifeboats used by the Coast Guard.

6.5. Nomenclature. Figure 6.3 lists a number of parts for a wood hull. The names of these parts do not change to any marked degree regardless of the material used in building the boat.

6.6. Identification of Navy Boats. Reference to a particular boat in any detail should include both its length and type. For example "26-foot motor whaleboat." Landing craft, however, are properly designated by the abbreviated name, such as "LCM." The hull registry number should also be cited. This number is engraved or bead welded on the hull during construction, and also appears on the hull label place. When boats are painted or repaired, care must be taken to keep the registry number in a legible condition.

6.7. Barges and Gigs. Navy boats assigned for the personal use of flag rank officers are *barges*. Boats used by commanding officers and chiefs of staff not of flag rank are *gigs*. The following types of standard boats are often modified and assigned for use as barges or gigs: 26-foot, 28-foot, 33-foot and 40-foot personnel boats, 35-foot and 40-foot motorboats, 36-foot LCPL. The

NOTES
In general nautical usage, the upper rail of the boat is called the gunwale. The floors lie along side the frames across the bottom of the boat only

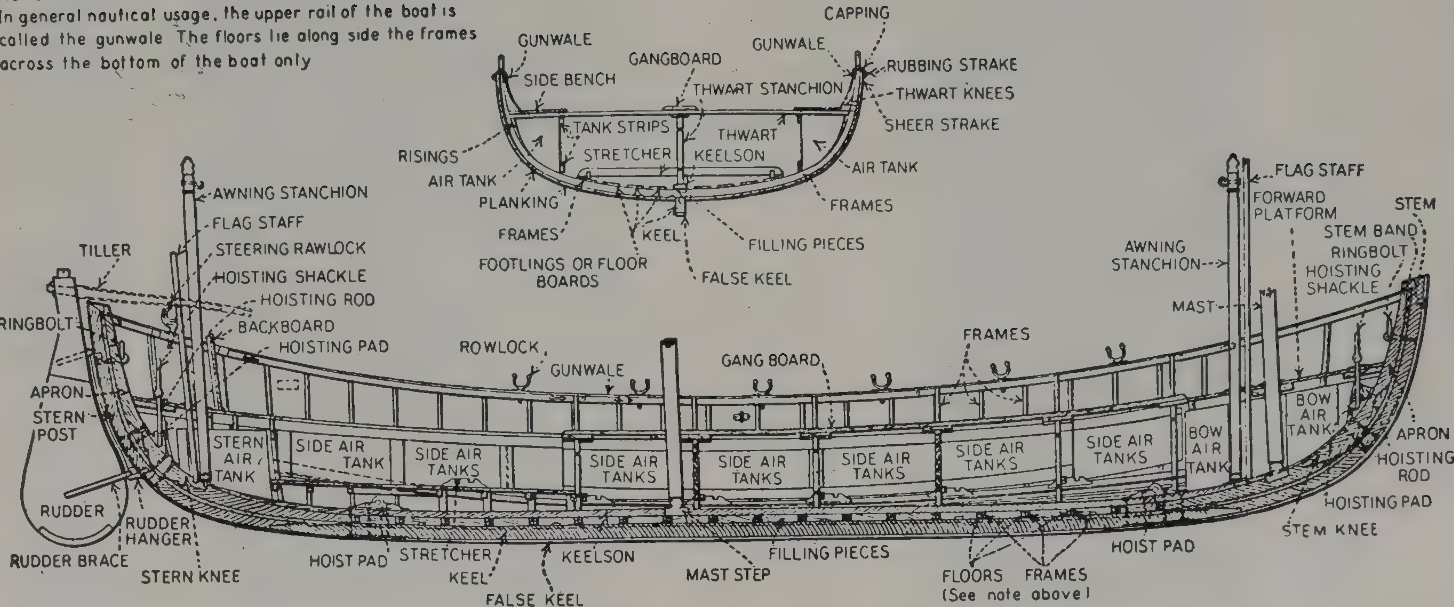


FIG. 6.3 PARTS OF A BOAT

exterior hull of a barge is painted black. Other Navy boats and craft are painted haze grey.

6.8. Upkeep and Maintenance. Wooden boats require special attention in providing ventilation and drainage, and the prevention of leakage. To this

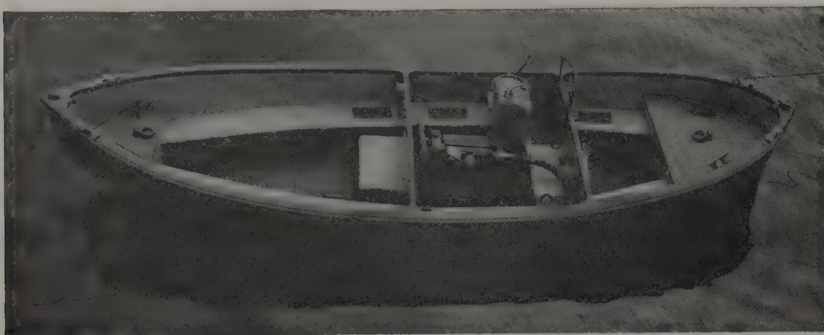


FIG. 6.4 26-FOOT MOTOR WHALEBOAT MK 5 (PLASTIC)

end, all ventilation terminals should be kept open. The lazarette, stern, and bilge areas should be provided with a reliable means of ventilation. Standing fresh water, even in small amounts, is particularly harmful.

Deck seams, in the plank sheer area especially, must be carefully calked and maintained. Decks must be sanded with care to retain the proper camber

FIG. 6.5 LANDING CRAFT MECHANIZED (LCM 6)

and to prevent low areas where fresh water would tend to stand. During fair weather, hatches and deck plates of boats afloat should be opened to increase air circulation. Wet dunnage, rope, and life jackets in lockers and forepeak spaces should be removed and aired out.

Wooden boats should not be washed down with fresh water. Salt water, which has some preservative value, should be used instead. For removing salt accumulations from varnished surfaces, chrome and brass fittings, and windows, the use of fresh water is recommended.

Boat crews must be alert for any leaks beneath the covering board or the deckhouse. Moisture is trapped by thick coats of paint, so over-painting must be avoided. On some wooden boats the stem, stern, and bilge areas are purposely left unpainted. In such areas, wood preservative solutions rather than paints are used.

Steel boats call for added care in the matter of corrosion prevention. Proper upkeep of paint and other coatings in all interior and exterior surfaces is a necessity. The proper number of zincs must be installed in the stern area on steel hulls (as well as on some wood and plastic hulls) to prevent electrolytic corrosion.

6.9. Care of Equipment. Propeller shaft alignment should be checked regularly. Crank case oil should be changed after every 100 hours or so of running time. Boats alongside one another should be separated by boat fenders. When the boat is lifted from the water, the struts, propeller, sea suctions, and shaft bearings must be checked. Worn propellers or worn shaft bearings bring on heavy vibration, eventually damaging hull and engine. Gear housings, steering mechanisms and other moving parts must be kept well lubricated.

It is not possible to paint or calk oil-soaked bottom planking in wooden boats. An oil-soaked bilge is a fire hazard in any boat. When draining or filling fuel tanks or engine crank cases, avoid spillage.

Wooden blocking and wedges should support a stowed boat's overhang both fore and aft. Chocks should be located opposite frames or bulkheads. In order to spread the stress, the loads imposed by gripe pads should be distributed as widely as possible. Take-up devices on the gripes should be marked at the limit of the tightening required.

6.10. Hoisting and Lowering. Most boats are equipped with fittings for hoisting and lowering. The hoisting fittings and pads should be inspected before each lift to check that all nuts are secure and that all cotter keys are in place. The slings must also be inspected before each lift and should never be used if they are frayed. During the ship's regular overhaul, the hoisting fittings, pads and slings should be given a 50 percent overload test. The hoisting slings used for lifting a boat with a crane are given a 100 percent overload test when made up. Slings for one type of boat should not be improvised for use on another type.

Ships have devices for hoisting and lowering boats. When hoisted (or lowered) by a ship's *crane*, the boat's *hoisting slings* are used. When hoisted at the *davits*, the boat's *fore-and-aft shackles* are used. The Raymond releasing hook is a standard release device used for attaching or releasing the davit falls from the davit shackles installed in the boat. It is a swivel hook with a

tripper hinged at the bill of the hook. The tripper is so weighted at its outer end that when the boat is waterborne and the load is removed from the hook, it automatically tumbles, thus throwing the boat shackle out of the hook and releasing the boat.

When the boat is not waterborne, the load on the hook prevents the tumbling of the tripping device. To speed up "hooking on" prior to lifting the boat, the weighted end of the hook is provided with a lanyard, which is passed through the shackle and held taut in order, first to prevent tumbling of the tripper, and, second to hold the shackle in the hook prior to hoisting. This is not difficult in a flat calm but normally the ship is rolling as the boat rises and falls. This is why many boat crews wear hard hats or helmet liners. The *bow hook* should be strong, agile, and steady in order to do his job and to avoid a swinging hook both while hooking on and after release.

6.11. Boat Davits. Gravity, sheath screw, quadrantal, and radial or round bar are the usual type davits. With the *gravity type davit,* the boat is carried in two cradles mounted on rollers. The rollers ride along two parallel tracks at right angles to the ship's side. After the gripes are released, a brake is released. This action permits the boat and the entire assembly to roll down the tracks by gravity, stopping with the lifeboat suspended over the ship's side. Tricing lines swing the boat against the ship's side and hold it in position until frapping lines are passed around the falls and secured, thus holding the boat in position to receive people aboard. After this, the tricing lines are cast adrift by tripping the pelican hooks before the boat is loaded. The next action is that of releasing the brake, which causes the boat to be lowered to the water. A Falls Tensioning Device on modern gravity davits maintains a constant and safe tension on the boat during lowering and hoisting.

With *sheath screw type davits,* the boat is carried either on chocks under the davits or is cradled between the davits. The davit, which is pivoted near the foot, is rotated outboard by a crank operating a sheath screw. This action swings out the boat.

With *quadrantal type davits,* the boat is carried on chocks under the davits. The davits themselves stand upright with the tops curved in toward each other so that the ends come directly above the hoisting hooks of the boat. The davit, which pivots, is turned outboard by a crank operating a worm gear.

With *radial or round-bar type davits,* the boat is carried in chocks, under the davits. Like the two preceding types, these also pivot. Chapter 13 includes a detailed description of the use of radial davits.

Two commercial davits are the *Rottmer* and the *Steward.* These feature releasing hooks in each end of the boat to which the falls are attached. Hinged on pins, the hooks are held engaged by a locking device. A jointed shaft running the length of the boat is connected to both locking devices. Upon throwing a lever attached to this shaft, the hooks are capsized and the boat released.

The *Mills chain* releasing mechanism is also common in the Merchant Navy. The gear-release handle is conveniently located on deck at the after end of the boat. When this handle is pulled, trigger hooks with ball weights (to which the boat falls are made fast) drop. The boat is then free fore-and-aft. Before the releasing gear can work, the boat must be waterborne.

6.12. Label Plate. Boats in the Navy are fitted with a label plate, which provides data about its design, manufacture, and maximum capacity. The latter is calculated in terms of carrying capacity of men. (About 10 cubic feet of internal volume per man, based on a average weight-per-man of 165 pounds, fully clothed and wearing a life jacket.)

6.13. Some Specific Boat Types. A boat's design is determined largely by: mission or purpose, cargo or personnel capacity, speed, minimum maintenance, weight in event shipboard stowage is required.

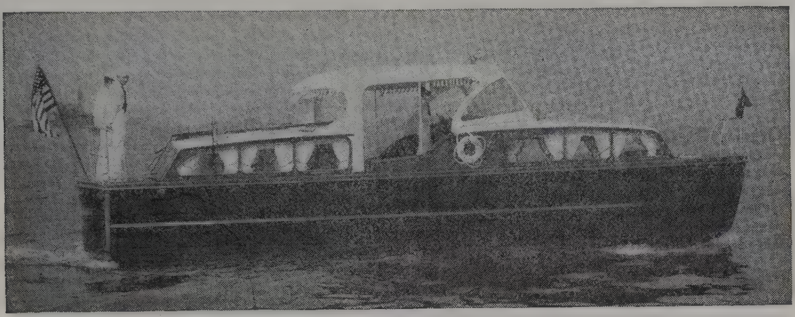


FIG. 6.6 35-FOOT MOTORBOAT (ADMIRAL'S BARGE)

FIG. 6.7 40-FOOT UTILITY BOAT

Dinghies are small boats (about 9 feet long) carried aboard somewhat larger craft, such as landing craft and rescue boats. They are a general tender, and can, on occasion, provide transportation for the crew. When equipped with sail, a dinghy also is used for recreation. It is normally equipped with a pair of oars.

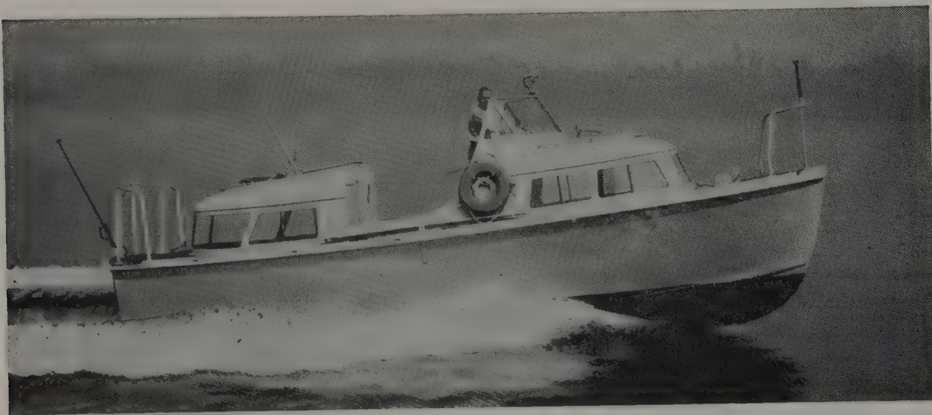


FIG. 6.8 28-FOOT PERSONNEL BOAT

Punts are general-purpose workboats, square ended, and usually used for work along the ship's waterline. Though equipped with oars, they are usually propelled by sculling. *Wherries* are larger versions of dinghies, and used for the same general duties.

Motor whaleboats are built along the same hull lines as the pulling whaleboats of whaling days. They are necessarily heavier, and their weight makes

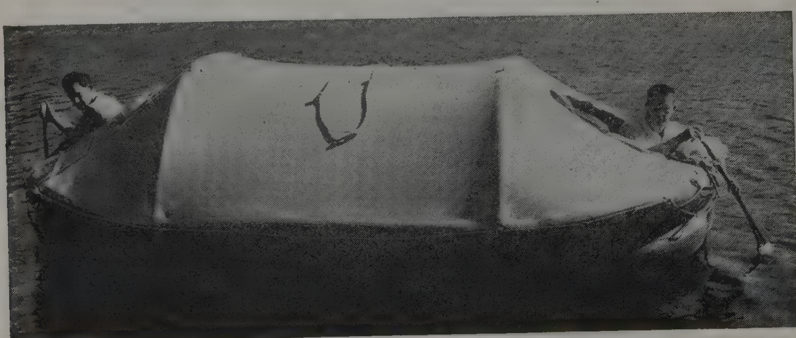


FIG. 6.9 INFLATABLE LIFEBOAT MK III

them considerably less seaworthy. Originally made of wood, motor whaleboats are now made of plastic and are equipped with a wheel and rudder in lieu of a tiller or steering oar.

Personnel boats are similar to commercial cabin cruisers. They carry personnel and are largely replacing the officers' motorboats.

Utility boats are used to transport personnel and cargo. Assigned mainly to shore-based boat pools at first, they are now replacing the shipboard motor launch.

Inflatable lifeboats are carried aboard most Navy ships. They require periodic inspection and testing so that they will function properly when needed.

6.14. Amphibious Craft. The *landing craft vehicle or personnel* (LCVP) is the most common type. Many thousands are in use—mainly as utility boats—but they are being phased out slowly. The *landing craft personnel, large* (LCPL), another important type, is used for the control of other landing craft in an amphibious landing, and is equipped with communications gear and radar.

Largest boat used in the Navy is the *landing craft mechanized* (LCM). The LCM (6) is a little over 56 feet in length and has a hoisting weight of 56,000 pounds. The LCM (8) is more than 73½ feet in length and 21 feet in beam. Her hoisting weight is 134,000 pounds.

6.15. Experimental Craft. The *hydrofoil boat* shows great promise. Though still experimental, continuing evaluation is proving the versatility of this advanced form of watercraft. The hull is similar to that of the conventional

FIG. 6.10 BOAT EQUIPPED WITH HYDROFOILS

boat. However, both fore-and-aft, attached to the hull are hydrofoils which provide lift in the same way that the wing of an airplane does. As the speed of the boat increases and she commences to plane, the boat rises and rides on the foils. The foils, being relatively small in comparison with the bottom of the hull, greatly decrease water resistance. Thus the boat is capable of high speeds.

The *ground effects machine* (GEM) is another new form. This craft rides on a powerful blast of air blown beneath the hull by ducted air fans, the air being retained by a special skirt built around the hull bottom.

6.16. Boat Capacity. When people are carried, the designated carrying capacity should not be exceeded; in carrying stores, the load in pounds (of

both men and stores) should not exceed the maximum allowable cargo load. Passengers, stores and baggage should not be carried topside on motorboats. If stores and baggage are carried in motorboats, the number of passengers should be reduced.

6.17. U.S. Coast Guard Boats. The *52-foot motor lifeboat* is designed for rescue work in rough seas. A double-ender, it is steel-hulled with the superstructure and interior trim being made of aluminum alloy. The diesel engines drive twin screws. Other features are: fire and salvage pumps of a 500-gallon-

FIG. 6.11 MOTOR SURFBOAT, 26-FOOT (FIBERGLASS CONSTRUCTION)

per-minute capacity, improved visibility and protection at steering stations, power-driven windlass and capstan, forced ventilation and electric heating for the compartments.

The *40-foot utility boat* is a general-purpose, twin-screw diesel-engined craft that meets requirements for light rescue, security, and off-shore duty.

The *36-foot motor lifeboat* is a heavy-duty, steel-hulled, self-righting nonsinkable lifeboat. Capable of action in heavy storms, this craft is a Coast Guard standby.

The *44-foot motor lifeboat* is a larger, later, and more advanced craft than the preceding. It has a crew of 3, but a capacity for 40 men, with a 16-knot speed and a 150-mile cruising range, it is well suited for its search and rescue duties—and is so designed that it handles well under heavy sea and surf conditions.

The *30-foot utility boat* is similar to its 40-foot big brother, with many of the former's features. A diesel-powered, single-screw craft, it is designed for light rescue, security and off-shore work. The hull is of reinforced mahogany.

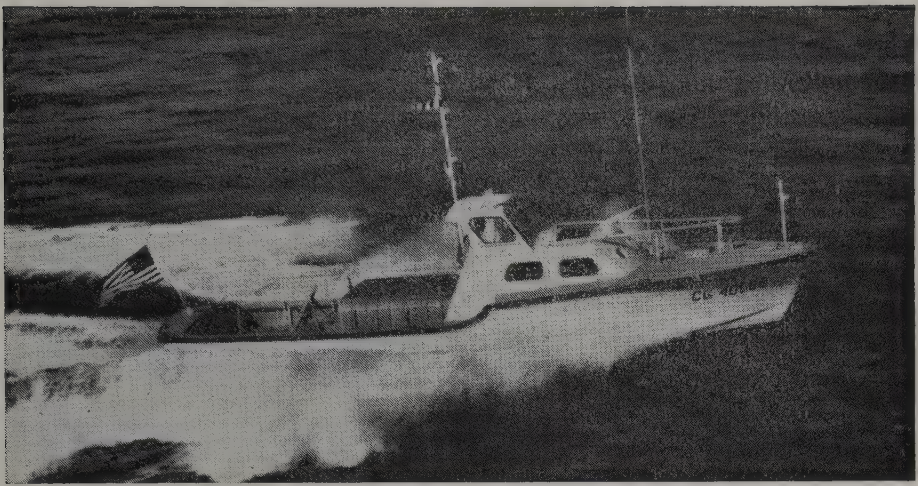


FIG. 6.12 U.S. COAST GUARD 40-FOOT PLASTIC UTILITY BOAT

The *26-foot pulling self-bailing surf boat* is carvel built and oar propelled. It is steered by a sweep, and is light enough to be moved by trailer along the beach and launched on the beach. Even smaller is the *16-foot (plastic) outboard motorboat.* Manned by a boarding team, this boat is powered by a 35-h.p. outboard, and used chiefly on inland waters.

U.S. Merchant Marine Boats

6.18. Definitions. In the U.S. merchant marine the terms *boats* and *lifeboats* are practically synonymous. In fact, the regulations governing lifeboats (and life rafts, life floats and other buoyant devices) are listed in the "Lifesaving Equipment" portion of the pertinent U.S. Coast Guard regulations. Listed below are excerpts from those regulations.

". . . all vessels shall be provided with sufficient lifeboats on each side of such aggregate capacity as will accommodate half the total number of persons on board."

"Lifeboats shall be not less than 24 feet in length, except where owing to the size of the vessel, or for other reasons, the Commandant considers the carriage of such lifeboats to be unreasonable or impracticable. However, in no case shall lifeboats be less than 16 feet in length."

"Emergency lifeboats: One of the lifeboats on each side of the vessel shall be of suitable size and design for performing emergency work at sea. Such lifeboats shall be not more than 28 feet in length and the ratio of length to beam shall be not less than 3.3. They shall be kept ready for immediate use while the vessel is at sea."

"All vessels shall be provided with the minimum number of motor lifeboats . . ." (As shown below) "In those cases where at least two motor lifeboats

are required, these shall be one on each side. On vessels of over 2500 gross tons which in the normal course of their voyage are at any point 200 miles offshore, if a Class 3 motor lifeboat is not installed, an approved portable radio unit shall be carried by the vessel . . ." (In addition to one required elsewhere by regulations.)

TABLE 6.1. LIFEBOAT REQUIREMENTS

Total Number of Persons Carried		Minimum Number *Class 2* *Motor Lifeboats*	Minimum Number *Class 3* *Motor Lifeboats*
over	*not over*		
—	30	1	—
30	199	2	—
199	1500	1	1
1500	—	—	2

6.19. Classes of Merchant Marine Lifeboats. There are three classes of such lifeboats.

"A Class 1 motor lifeboat is one that is fitted with a compression ignition engine, is capable of being readily started in all conditions, and has sufficient fuel for 24 hours continuous operation. The speed ahead in smooth water when loaded, with its full complement of persons and equipment shall be at least 6 knots."

"A Class 2 motor lifeboat shall meet the Class 1 requirement, and in addition, shall be fitted with a search light . . ."

"A Class 3 motor lifeboat shall meet the Class 2 requirements, and in addition, shall be fitted with a radio cabin and a radio installation complying with requirements of the Federal Communications Commission." "All lifeboats certified to carry 60 or more but not over 100 persons shall be motor lifeboats or shall be fitted with an approved type of hand-propelling gear. Lifeboats carrying more than 100 persons shall be motor lifeboats."

FISHING CRAFT AND EQUIPMENT

Commercial fisheries are of two general types: pelagic and demersal. Pelagic fish are those which live at or near the surface of the sea; demersal fish inhabit the sea bottom. Distinct craft and gear have evolved for catching each of these types of fish.

Pelagic fish include mackerel, herring, tuna, and shark. They habitually travel in schools that move rapidly through the upper layers of the ocean. The fisherman in quest of pelagic fish normally selects his fishing ground through past experience, then pinpoints his quarry by eye or by sonar. For visual search pelagic fishing craft are equipped with a high crow's nest and,

in the most modern vessels, a float plane or helicopter. For acoustic search, "fish-finders," both echo-sounders and scanning sonars, are used to locate schools of fish.

Once located, pelagic fish are taken by purse seines, drift nets, and hook and line. Purse seiners take most of the annual U.S. catch. A purse seine is a long deep net of small mesh. The seiner, usually with the aid of a work boat, lays the net in a circle around a school of fish and joins the ends. The bottom is then closed by a purse line strung through eyes along the lower

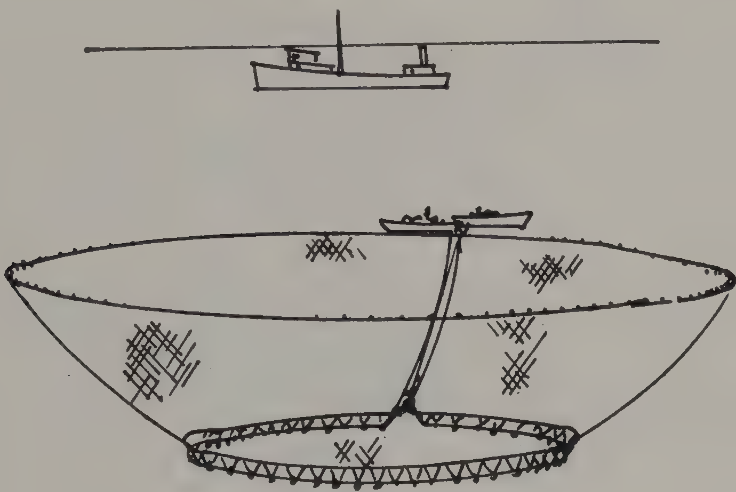


FIG. 6.13 PURSE SEINE

edge of the net. When hauled in, the purse line acts as a drawstring, gathering together the bottom of the seine and preventing the escape of the fish. (See Fig. 6.13.) The net is then brought on deck until the catch is concentrated in a small pocket which remains in the water. The fish are taken aboard by dip nets.

A typical American purse seine measures 200 feet by 100 feet. Heavy and expensive, it includes some 6000 cork floats, 6400 lead weights, 160 galvanized iron purse rings, and 300 fathoms of steel, nylon, or manila purse line. The cost may range into tens of thousands of dollars. Some nets are even bigger, with the world's largest said to be 580 fathoms in length and 52 fathoms deep.

Figure 6.14 shows a West Coast purse seiner. The seine is stowed on the low, wide fantail on top of a rotating turntable. A power-operated roller and a heavy boom and winch are used to handle the net. The high bow and bridge give excellent sea-keeping qualities, and the crow's nest gives the lookout good visibility. The workboat, if carried, is stowed atop the seine.

Smaller seines are handled by craft of similar but smaller design. They utilize a turntable and net-handling boom. In the Okhotsk and Bering Seas,

a crab fishery is worked by small Russian and Japanese seiners. Some of the seiners are based ashore, while others, because of the long distance from port and the lack of shore processing facilities, operate from mother ships. By caring for the needs of the seiners and serving as fish factories the tenders make long cruises feasible and economical.

Another pelagic fishing craft, the tuna clipper, uses hook and line. A Pacific type, it ranges far beyond the continental shelf in search of large tuna. Once a school is located, the clipper attracts them alongside by throwing overboard

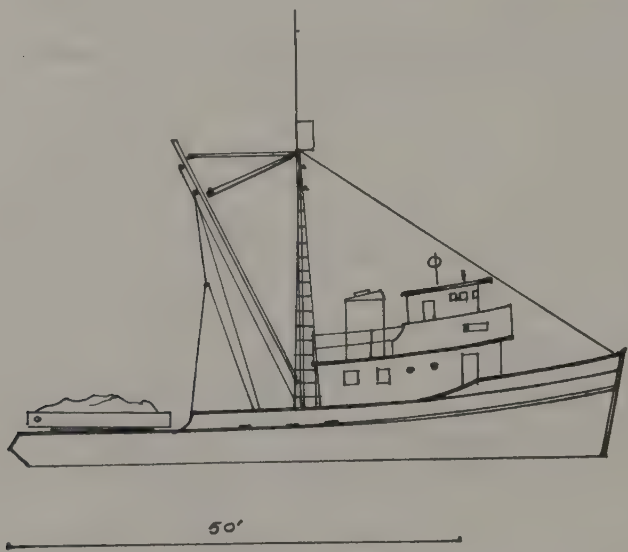


FIG. 6.14 WEST COAST PURSE SEINER

bait fish. The tuna are caught on large feathered, barbless jig hooks, two or three poles and lines to each jig. The hands swing the tuna on deck where they are shaken off the hook, cleaned, and struck below into refrigerated holds.

The tuna clipper in Fig. 6.15, like the purse seiner, is built for long voyages on the high seas. It has a high crow's nest for good visibility. The low stern facilitates swinging the catch aboard. A tank for carrying live bait is located aft, above the refrigerated hold. Cold storage capacity may be as great as 1000 tons. Clippers sometimes carry purse seines for catching smaller varieties of tuna, as well as smaller nets to capture bait fish.

Another common type of pelagic fisherman is the drifter. As illustrated by Fig. 6.16, drifting gear consists of long "fleets" of gill nets. Each net is about ten fathoms long by several fathoms deep. The mesh is larger than that of a purse seine, large enough so that fish can pass only part way through. They are then entangled in the mesh until brought on board and pulled free by the fishermen. The drifter "shoots" up to 100 nets in a

continuous line suspended near the surface by wooden or plastic floats. Nets are laid at dusk so that the fish cannot see them. Moored to the leeward end, the boat drifts until dawn—whence the name "drifter"—then the nets are hauled and the catch recovered. Sometimes they are hauled by hand, sometimes by a special winch or reel.

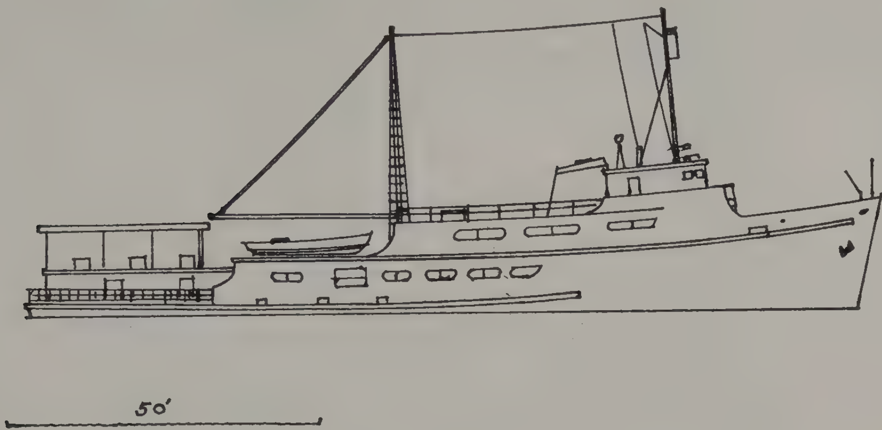


FIG. 6.15 TUNA CLIPPER

The drifter is the most important type of pelagic fisherman in European waters. A typical North Sea drifter is shown in Fig. 6.17. Designed to work grounds close to port, the drifter brings in its catch fresh. Slow and rugged, it has limited accommodations and few comforts. The foremast mounts

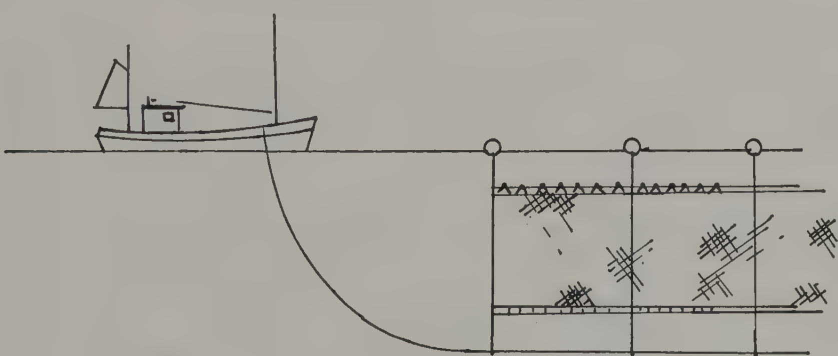


FIG. 6.16 DRIFT NET

a long boom for handling the catch. The mast is often mounted in a tabernacle so that it can be lowered to increase stability. The short mainmast carries a steadying sail to reduce rolling and keep the boat headed into the wind. Drifters vary in size from small 20-footers up to large modern ships of over 100 feet.

In many parts of the world pelagic fish are taken by trolling. The Bay of Biscay tunny fishery was worked for many years by sailing craft called *tonniers*. Ruggedly built yawls or ketches, they streamed their bait from long lines attached to *tagnons* or poles. The salmon fishery of the U.S. Pacific Northwest is also worked by trolling. A typical troller is shown in Fig. 6.18. Diesel powered, it is flush decked with mast and deckhouse forward. Six or eight lines can be handled, and a power winch is fitted to pull in hooked fish.

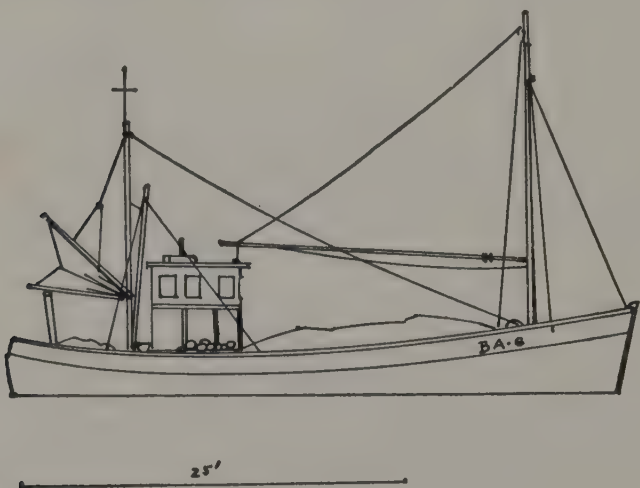


FIG. 6.17 NORTH SEA MOTOR DRIFTER

Whales, although mammals, comprise a pelagic fishery. Operating in the far South Pacific, whaling fleets sail under the flags of Norway, Great Britain, South Africa, Japan, and Russia. A highly organized operation, whaling is carried out by flotillas which include store ships, tankers, factory ships, whale catchers, carcass towers, and aircraft. A whale catcher is a fast, maneuverable craft mounting a harpoon gun. Its job is to pursue the whale, harpoon it, buoy the carcass, and be off after another whale. The carcass is towed to the factory ship where it is hauled aboard and processed.

A whale catcher is shown in Fig. 6.19. Steam propelled, it can make about 15 knots. A catwalk leading to the bridge allows the harpooner to man his gun even in heavy seas.

Cod, flounder, pollack, and shellfish are among the most important demersal fish. They are usually taken by trawling. Although commonly applied to many types of fishermen, the term "trawler" should be reserved for vessels that use trawls. An otter trawl is sketched in Fig. 6.20. The trawl is a large-cone-shaped net bag. Its forward end is spread open either by a beam, in the smaller sizes, or by a pair of otter boards or "doors." Weights, in the form of steel bobbins or chains, hold the lower edge of the mouth on the bottom, while steel or aluminum floats on a head rope hold up the upper

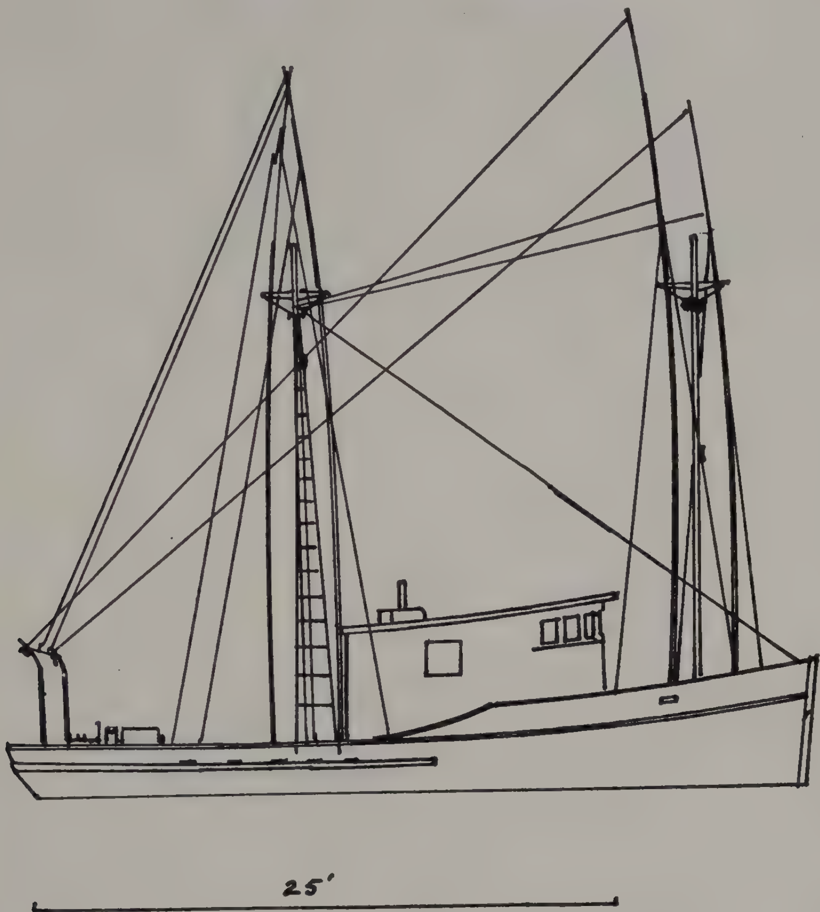


FIG. 6.18 SALMON TROLLER

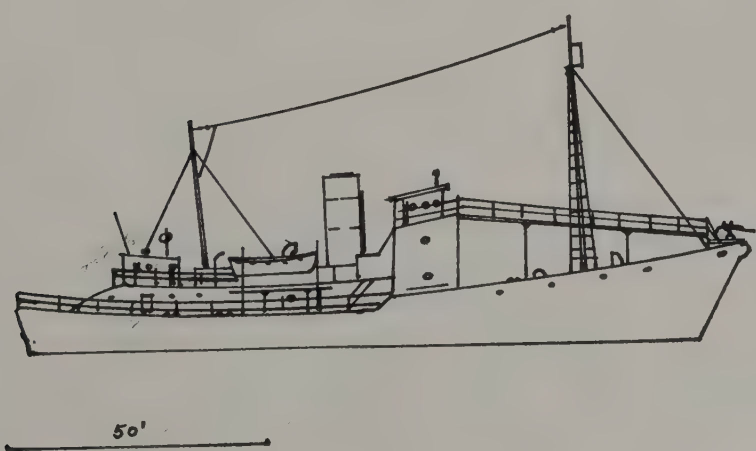


FIG. 6.19 WHALE CATCHER

edge. Otter boards are heavy door-shaped structures of steel or wood strengthened with steel. Rigged to tow at an angle like underwater kites, they can hold open a trawl mouth over 100 feet wide and 15 feet high. Long warps allow the trawl to be dragged along the bottom in waters as deep as 200 fathoms. The rugged construction of a large trawl permits catches of 25,000 pounds or more. Development is underway in many countries to improve trawl designs, both as to underwater performance and easier handling on deck.

Conventional trawlers handle the trawl over the side. Each of the two warps is led over the deck edge through a large block suspended from a

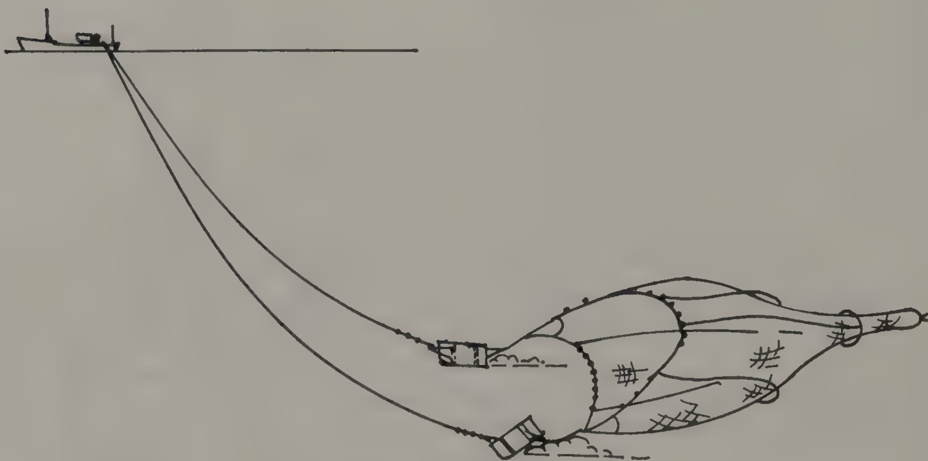


FIG. 6.20 OTTER TRAWL

heavy A-frame called a "gallows." Small trawlers have gallows on only one side; larger vessels may have one pair on the port side and another pair on the starboard. In either case, the gallows are a certain mark of the trawler.

To stream his gear, the trawler lies to across the wind. He then lowers the trawl over the side and begins to circle around it. As he approaches the trawling course he lowers the otter boards. The warps are paid out as the trawl doors set properly. In 200 fathoms of water, about 450 to 600 fathoms of warp are used. The warps are led to a special hookup or towing block on the inboard quarter, and the vessel steadies on trawling course at two or three knots. After a run which may last for several hours, the trawl is hauled back by winches. The net is brought alongside and hauled on board. The cod end is opened and the catch dumped on deck. If the ground is especially good, it may be marked with a buoy for future reference.

Trawlers vary widely in size. Among the smallest are the New England "draggers." With good fishing close by on the continental shelf, short cruises and frequent trips to the grounds are feasible. The design which has resulted is shown in Fig. 6.21. Normally of 100 feet or less, the typical dragger is

diesel propelled and mounts two masts with a steadying sail aft. Sturdy and seaworthy, they operate year around in the stormy North Atlantic.

The North Sea, an important trawling ground, is worked by craft not unlike the New England draggers. Many of the North Sea trawlers are old, however, and are characterized by steam propulsion with high, prominent stacks.

Distant ground trawlers are operated by several nations including Great Britain, Spain, Portugal, France, Japan, and Russia. Built for long trips and

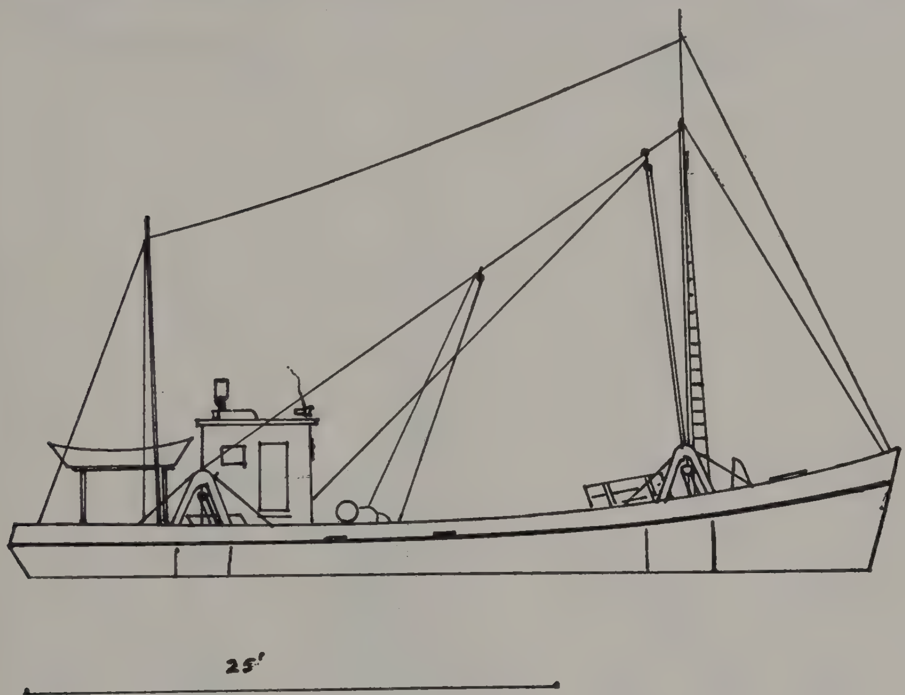


FIG. 6.21 NEW ENGLAND DRAGGER

large catches, they are strong ships with heavy gear and machinery. They range in size to over 200 feet and 500 tons. British trawlers work the Barent's Sea; French trawlers operate on the Grand Banks; and Russians are frequently seen off the East Coast of the U.S. A typical British craft is shown in Fig. 6.22.

An important fishery in the Gulf of Mexico and in southern U.S. waters is shrimping. A typical shrimper is shown in Fig. 6.23. It streams two or three small otter trawls, rigging the warps through blocks mounted on outriggers. Motor driven, shrimpers generally work shallow coastal waters but sometimes range across the Gulf of Mexico to Campeche.

The most modern development in demersal fishing is the stern trawler. Net handling over the side is a slow procedure, often hazardous in heavy weather.

Damage to gear and catch is possible, and automation is infeasible. By shifting the trawl to the stern and installing a sloping ramp, it has become possible to reduce manhandling and to locate the men in a safer position. The trawl

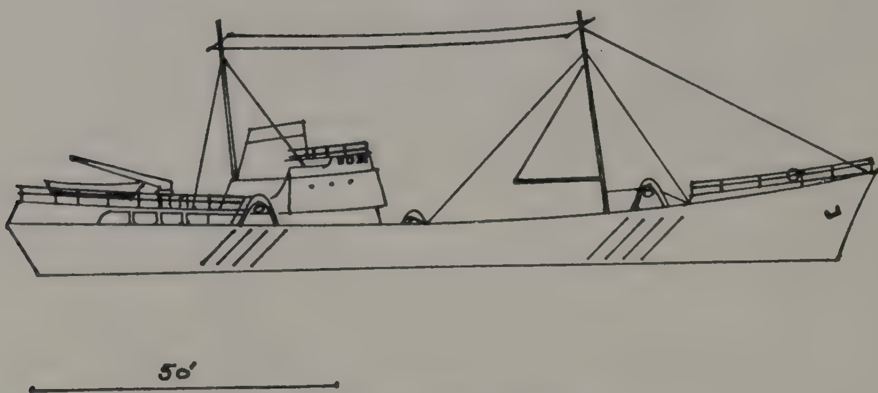


FIG. 6.22 TRAWLER (European)

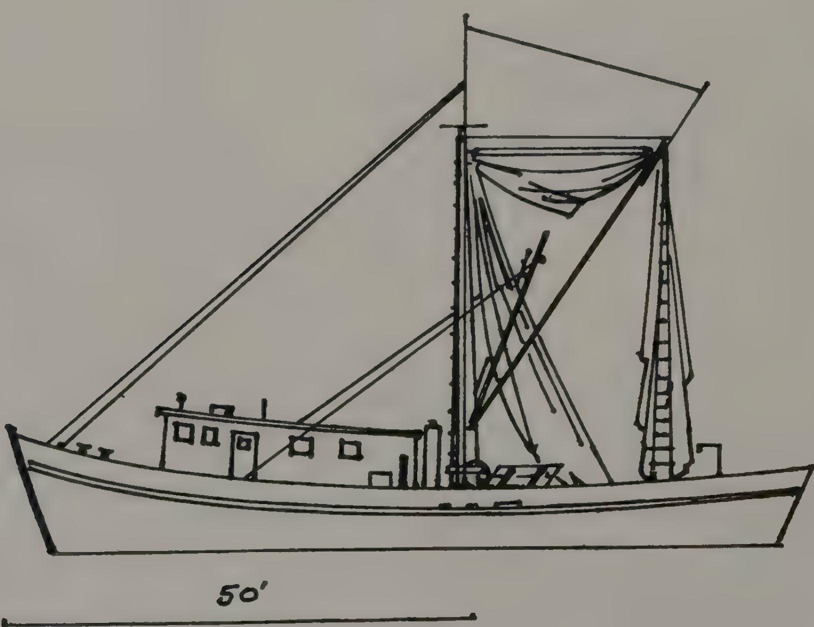


FIG. 6.23 SHRIMP BOAT

warps are run through blocks on the quarters, slung either from gallows or from a U-shaped gantry. Winches amidships haul in the warps and in some cases coil the trawl on a drum. The blocks, winches, rigging, and deck fittings are designed for remote operation, often by a single man. In some cases a

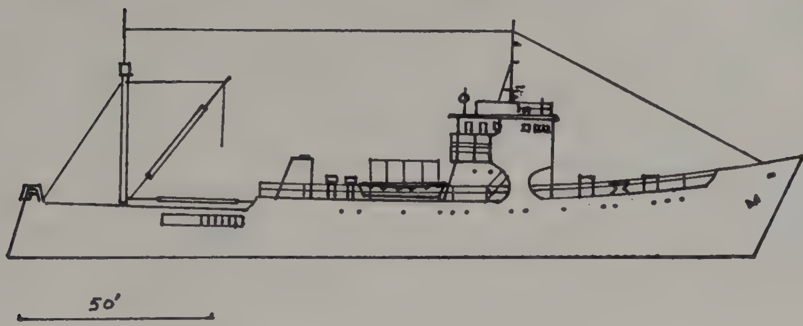


FIG. 6.24 STERN TRAWLER (Soviet Bloc)

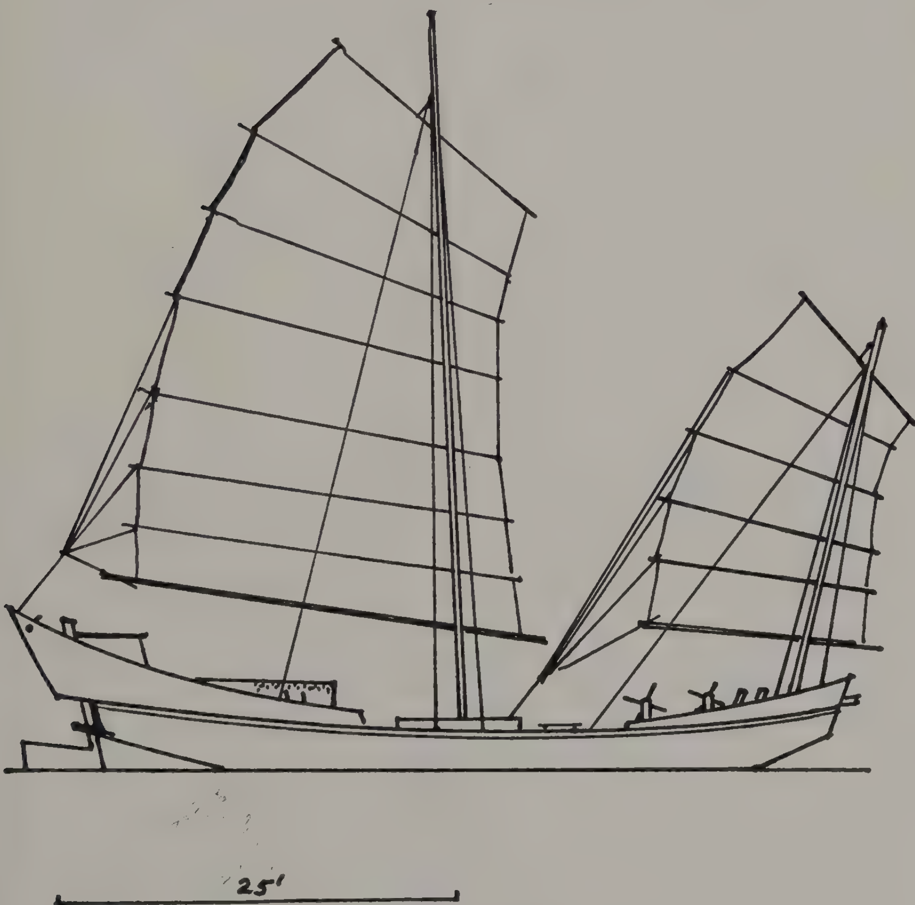


FIG. 6.25 YELLOW SEA FISHING JUNK

hydraulically operated door can be raised to close the after end of the slipway for added safety. Reduction of personnel and increased speed of operation are important economic factors, and stern trawlers are becoming more numerous. They now sail from ports in Europe, Africa, and the U.S. A Soviet bloc stern trawler and fish factory is sketched in Fig. 6.24. This class features an unusually long slipway and a novel stack arrangement with twin funnels located port and starboard of the fish deck.

Another demersal method is pair trawling. In this system two craft steam on parallel courses, towing between them a trawl which may be as wide as 300 feet. Pair trawlers tend to be small or medium size. They are fitted with

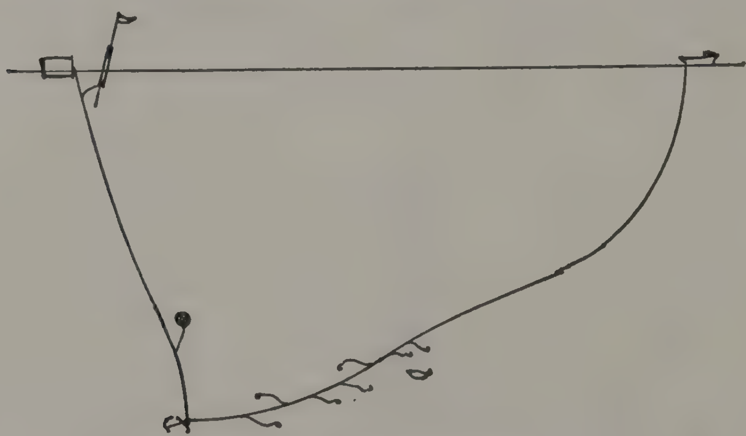


FIG. 6.26 LONG LINE (Bottom)

winches and do not require gallows. The junk shown in Fig. 6.25 is a pair trawler typical of those found in the Yellow and China seas. Large hand-powered windlasses, two masts, and a low silhouette distinguish it from larger, bulkier cargo junks.

The "long line" is used for demersal fishing the world over. Baited hooks are secured every two or three fathoms to a heavy hemp or wire line. (See Fig. 6.26.) After one end is buoyed and anchored, the boat pays out the line along the chosen track. When the entire line is set the far end is buoyed and anchored, and the boat returns to the starting point. The end is hauled aboard and the boat works its way along the line, removing the catch and rebaiting the hooks. Lines of 100 fathoms are handled by one or two men in an open boat. Off the American West Coast and in northern European waters, medium-sized vessels run lines up to 15 miles in length. They are fitted with power winches called "gurdies" to bring the line aboard. Distant water long liners are termed "dorymen." Similar in design to long range trawlers, they carry nests of one- or two-man dories. Among the few modern sailing fishermen are Spanish and Portuguese dorymen that work the Grand Banks. Utilizing

their diesel auxiliaries for the long voyages to and from the banks, they conserve fuel by using sail while on station.

There are many variations of the gear and craft described above, and many have local names. Fishery research continues to produce new types of gear. Midwater trawls whose depth can be controlled are entering the pelagic fishing picture. There is also a trend towards combining two or more capabilities in a single hull for increased flexibility and greater profits per voyage. Modern technology will continue to improve on traditional methods, but fishing boats, like their crews, will continue to be rugged and seaworthy.

7

Communications

As used here, communications is the act or fact of sending or passing information and receiving it; also, the ways and means of doing so. It is, for those on the seas, a subject of special importance. A ship's officer cannot be considered an expert in seamanship until he learns to employ communications effectively.

There are two types of communication: internal and external. The latter is *telecommunications,* which is rapid communications at a distance by visual, wire, radio or other electronic systems. A ship also has its internal or *interior* systems, such as public address, telephone, engine-order telegraph, and in some cases, sound-powered telephone and dial telephone systems.

7.1. Interior Communications. A ship's interior communications (IC) equipment is normally less complicated than that used for exterior communications. IC equipment is essential for the orderly performance of both emergency and routine shipboard functions. IC systems are generally classed as either an *indicating* or a *sound* system.

7.2. Interior Indicating Systems. There are usually one or more sound systems to provide alternate or backup communications for the indicating systems between vital locations, such as the bridge and main engine control. An indicating system helps prevent the orders being misunderstood during battle or emergency conditions or in spaces that have a high noise level, and it generally employs a synchronous motor system to transmit information or orders. Not all ships have all systems, however some are briefly described here.

Engine order telegraphs (annunciators) provide the conning officer a rapid and reliable means of ordering and receiving acknowledgement of changes in engine speed or direction. This is accomplished with two sections. The *engine order* section controls the speed range ("standard," "full," etc.). The *propeller order* section controls speed within a range.

Rudder angle indicators, which show the actual position of the rudder, are a valuable aid when maneuvering the ship.

Course to steer indicators provide the conning officer and helmsman the course to steer, as directed by navigational or weapons-control devices.

Navigational instruments, such as the gyrocompass, the pitometer log and

the wind direction and force indicators are also forms of interior indicating systems.

7.3. Interior Sound Systems. While indicating systems communicate only raw facts or orders, sound systems can amplify and make recommendations on the information that has been transmitted by the indicating systems. Since the voice is used, the scope of information is almost infinite.

Sound powered phone systems make up the mainstay of internal communications in Navy ships. These phones require no external power, and thus are reliable under all conditions. Speaking into the mouthpiece generates an electrical signal that is reproduced as sound on other phones on that circuit. Circuits may be (1) *direct*—a line connecting one or more outlets in the ship; (2) *switched*—lines passing through a switchboard, which allows one or more circuits to be connected together; or (3) *phone type*—lines between points with both a selector switch to select the desired station and a hand-crank growler or push-button buzzer to alert the station being called. Some systems pass through an amplifier to increase the volume. An automatic cutout will bypass the amplifier should the latter fail.

Multi-channel and *public address systems.* The former (squawk box) uses electronic amplifiers and push-button selector switches, allowing one or more stations to communicate directly. The latter are announcing systems only, having a no-receive capability.

Telephones. On larger ships the standard telephone is used. Normally it serves routine purposes; however, in emergencies it serves as an alternate system for operational purposes. Unlike the sound powered phone system, the number of stations that can communicate directly is determined by the type of equipment. Dial systems are replacing the older switchboard type.

Voice tubes. One of the oldest IC methods, these are still found in the most modern ships. This system of metal tubes connecting various stations is the least susceptible to damage.

7.4. Closed Circuit Television. A see-and-hear system, this is becoming increasingly important. It facilitates the rapid display of a fast-changing or complex picture. Examples of use aboard Navy ships would be the briefing of pilots and plane crews, using the tactical displays from the combat information center. Some merchant ships mount a TV camera on the pierside bow to facilitate docking.

Closed circuit TV transmits over wires the picture signal from the camera to the picture tube. In contrast, the commercial (or home) TV system transmits the signal through the air. TV holds promise as an *exterior* system, permitting see-and-hear communications between ships.

7.5. Telecommunications. In sharp contrast to the foregoing *internal* systems are those that provide rapid *external* communications. Telecommunications (rapid communications at a distance) breaks down into these three major classes.

Electrical Telecommunications:

a. Radiotelegraph
b. Teletypewriter
c. Radio-teletypewriter
d. Radiotelephone
e. Television
f. Facsimile

Visual Telecommunications:

a. Flaghoist
b. Flashing light
c. Semaphore
d. Pyrotechnics
e. Colored lights

Sound Telecommunications

7.6. Electrical Telecommunications. Radiotelegraph (often called CW for "continuous wave") is a system for transmitting messages by a radio wave which an operator separates into the dashes and dots of the Morse code by opening and closing a hand key. Radiotelegraph was in use by the Navy as early as 1903; and even today, in spite of the development of faster and more convenient methods, it remains one of the most reliable and trustworthy of systems.

The teletypewriter uses electrical and mechanical actions to perform the code-sensing action of the hand-key operator. To transmit a message the operator types on a keyboard similar to that on a typewriter. As each key is pressed, a sequence of signals is transmitted. At receiving stations the signals are fed into receiving machines, which type the message automatically.

Teletypewriter signals may be sent either by landline or by radio. Landline teletypewriter communication is used both by the military services and by commercial communication companies. Radio-teletypewriter (RATT) is primarily intended to furnish high-speed automatic communication over ocean areas. Today the primary shipboard use of RATT is for receiving fleet broadcast schedules. Radio-teletypewriters can clear traffic at a rate up to 100 words per minute as compared to the 18 to 25 wpm speed of the CW fleet broadcasts. Since the shipboard operator is freed from manual copying, and hundreds of vessels may be receiving a single broadcast, the total saving in trained manpower is considerable.

Radiotelephone (sometimes called voice radio) is one of the most useful communication methods. Because of its directness, convenience, and ease of operation, radiotelephone is used by ships and aircraft for short-range tactical communication. There is little delay while a message is prepared for transmission, and acknowledgements can be made instantly. Radiotelephone equipment is usually operated on frequencies that are high enough to have line-of-sight characteristics—i.e., the waves will not follow the curvature of the earth. This limits the usual range of radiotelephone from 20 to 25 miles, thus giving a certain degree of security. Radiotelephone procedure can be learned fairly easy.

Through a ship's radiotelephone, the nearest commercial shore "marine operator" can link voice radio communications of a ship with any "party" ashore having a conventional telephone.

With the advantages of radiotelephone go some disadvantages. Transmission

may be unreadable because of static, enemy interference or a high local noise level. Wave propagation characteristics of radiotelephone frequencies are sometimes freakish, allowing transmissions to be heard at great distances, but not by the addressee.

Single side band (SSB) a relatively new technique in radiotelephone, greatly increases the range. In addition, SSB allows many more channels or circuits to operate within a given frequency spectrum. However, the increased range resulting from SSB means the relative loss of security when using this equipment.

Television holds promise in telecommunications for these purposes, among others:

1. Remote guidance of missiles.
2. Reception of reconnaissance data from aircraft.
3. Remote inspection of underwater salvage operations.
4. Simultaneous briefing of many commanding officers or aviators of a task force when the tactical situation is too urgent to permit duplication of weather data, charts, or other pictoral information.

Facsimile (FAX) resembles television in that it is a process for transmission of pictures. It is unlike TV in that (1) facsimile gives the receiving station a permanent record of the transmission while television does not; and (2) facsimile requires several minutes to transmit a picture twice the size of this page, while television sends a continuous stream of 30 pictures per second.

FAX is very useful for transmitting such matter as photographs and weather charts. The image to be sent is scanned by a photoelectric cell, and variations in the cell output due to the character of the picture are used to modulate a radio wave. At the receiver the signal operates a recorder which reproduces the picture.

Shipboard Communications Facilities

7.7. Merchant and Naval Ship Requirements. Since the requirements of merchant and naval ships will vary, the facilities and methods of operation will differ.

The merchant ship is basically a business tool. As such it must operate both efficiently and economically. Once loaded and underway for its destination, a merchant ship has little requirement for communications other than possibly to receive instructions for future trips or cargos. For this reason, most merchantmen carry only one radio operator and have limited radio station facilities. Merchant lines communicate with their ship throughout the world through the services of commercial radio networks. The radio operator's "on watch" period is normally determined by the times that he can best communicate with the shoreside radio station he is working.

Deck officers of merchant ships are required to know Morse code and be able to communicate at the rate of 6 words per minute on flashing light.

Passenger liners basically differ from cargo ships in increased radio facilities. As a service to the large number of passengers carried, the liner will have several radio operators to provide round-the-clock radio and high seas telephone service.

Navy ships have a greater requirement for communications than the merchant ship. Naval ships must be able to communicate instantly 24 hours a day. Further, they usually operate in formation rather than singly.

7.8. Communication Coordination Facilities. For rapid exterior communications, ships have two main stations from which messages and signals are sent and received. These stations are known as the radio station and the visual station. Coordination of both stations in large warships takes place in the communication center under the supervision of the communication watch officer (CWO). The communications center is usually located in the vicinity of the main radio room (Fig. 7.1) or radio central.

At the visual station there are semaphore flags, portable signal lights, and a loud hailer ("bull horn" or electric megaphone). Signal flag hoists and flags are

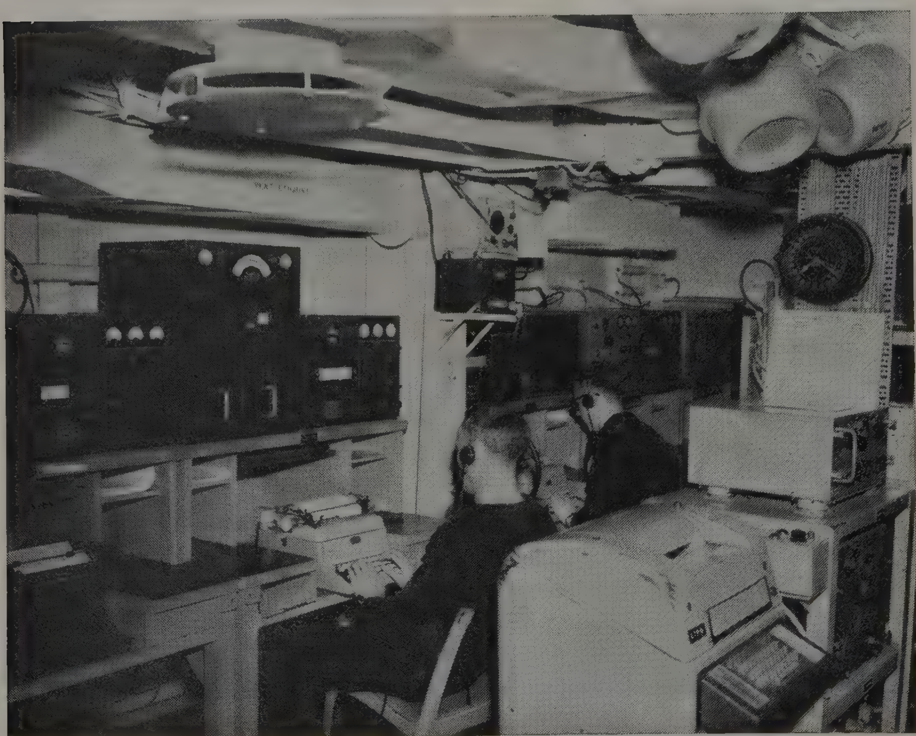


FIG. 7.1 RADIOMEN COPY CW CODE IN SHIP'S MAIN RADIO ROOM

in the vicinity. A ship's bell and whistle are nearby. Running lights and other navigational and anchor light fixtures are located on the masts, superstructure, and above the main deck; controls are near the visual station—usually in the pilothouse. Signal searchlights are in the superstructure in the vicinity of the visual station; blinker lights are installed on the yardarms with keying controls at the visual station. Pyrotechnic devices are located near the signal bridge.

The radio station facilities are concentrated mainly at radio central. Radio antennas are located throughout the superstructure. Radio transmitters and receivers are found not only in radio central but in special transmitter rooms and separate radio rooms. Portable and emergency radio equipment is located in a number of places. Remote operated radiotelephone units—send/receive facilities—are found on the bridge, in the pilothouses, CIC, and in radio spaces. Radioteletype and radiotelegraph facilities are normally operated at the main radio station.

A number of interior communications systems are employed to link the bridge and pilothouse with the key shipboard communication facilities. Regular telephones as well as sound powered telephones are used. Voice tubes are also used, and on some ships pneumatic tubes are installed to send messages quickly. Amplifier type announcing systems (often referred to as "squawk boxes" or "intercom units") are widely employed also.

7.9. Visual Telecommunications. Visual communication systems have been in use since men first sailed the seas and are still the best means for communicating at short range. In reliability and convenience they are the equal of radio and are more secure.

The most important visual systems are flaghoist, flashing light, and semaphore. Pyrotechnics, colored light, and sound have important wartime uses.

Flaghoist is a method whereby various combinations of brightly colored flags and pennants are hoisted to send messages. It is the primary means for transmitting brief tactical and informational signals to other ships. Signals are repeated by addressees, thus providing a sure check on the accuracy of reception. Texts of messages which may be sent are limited to those found in signal books.

Directional flashing light is a visual telegraphic system in which an operator opens and closes the shutter of a searchlight to form the dashes and dots of the Morse code. The light may be pointed and trained to be seen only from the viewpoint of the receiver.

Nondirectional flashing light is sent out from a lamp on a yardarm. Dots and dashes are made by switching the lamp on and off. Since the light is visible in every direction, this method is well suited for messages which are for several addressees.

Semaphore is a communication method in which an operator signals with two

hand flags, moving his arms through various positions to represent letters, numerals, and other special signs. It is especially suitable for long administrative messages because of its speed. It is not readable much farther than two miles, even on a clear day.

Pyrotechnics have a wide variety of uses. Often their use can be a matter of life or death. Examples are identification of own ship or attracting attention when in distress. Coastal lifesaving stations also employ pyrotechnic flares to signal to vessels in distress.

Pyrotechnics used for signaling are, for the most part, of the fireworks variety. The term "pyrotechnic light" includes all types which provide a temporary source of light as opposed to pyrotechnic smoke. Common sources of pyrotechnic light are *Very* pistol flares, colored shell bursts (parachute flares), aircraft parachute flares, Roman candles, and float type flares. Common types of pyrotechnic smokes are also *Very* pistol bursts, colored smoke from shell burst, aircraft parachute smoke pots, float type smoke pots, smoke generators, and smoke puffs from surface ship smoke stacks. The meaning of a pyrotechnic signal is dependent on the color rather than on the type of pyrotechnic used.

The following limitations which are inherent in pyrotechnic signals can be considered guides in using them:

Signals consisting of a succession of pyrotechnics or a combination of colors should not be used, because there is the danger that an observer may not have seen the whole of the signal and may consequently misinterpret it.

The standard colors red, white (or yellow), and green are the only colors which give satisfaction under varying conditions of visibility. Under certain atmospheric conditions, white signals may appear as yellow; these two colors are therefore considered synonymous. Under certain conditions of humidity a white pyrotechnic is liable to be mistaken for green.

Tracer is particularly liable to be confused with red pyrotechnics. At a distance it is difficult to identify the exact position from which a pyrotechnic signal was fired; consequently, a single pyrotechnic fired by each of two separate originators may appear to an observer as two pyrotechnics fired simultaneously or in succession from one originator.

The range of visibility for "pyro" is largely dependent on weather conditions.

7.10. Semaphore Facilities. Semaphore requires little equipment—the two hand flags attached to staffs are all that is needed (Fig. 7.2). The standard semaphore flags are usually 15 or 18 inches square, and each staff is long enough to enable the sender to grasp it firmly. The flags are similar to the *oscar* alphabet flag. The *papa* flag is sometimes substituted. Most semaphore flags issued to the fleet today are fluorescent and are made of sharkskin cloth. The merchant marine no longer uses semaphore.

When fluorescent flags are used, background is not too important. When cotton flags are used, it is imperative that a good background be selected. Otherwise the other ship(s) may not be able to see the flags clearly.

FIG. 7.2 SEMAPHORE IN USE. *Official U.S. Navy Photograph*

7.11. Searchlights. Searchlights may be classified as incandescent and arc. In the 12-inch searchlight the source of light is a specially designed incandescent lamp. Control of the light is by means of a shutter. This is illustrated in Fig. 7.3. The front and rear doors are hinged to the searchlight case to permit access to the interior for relamping and cleaning. There is usually a handle on the rear of the case to elevate and depress the light or turn it in azimuth.

The Navy standard 12-inch searchlight is simple to operate. Anyone can learn in a short time the proper procedure for turning the lamp on and off, positioning it horizontally or vertically, and operating the shutters.

The carbon-arc 24-inch searchlight is intended primarily for signaling and secondarily for navigational use. It consists of a stationary pedestal which is secured to the searchlight platform, a turntable which carries the two trunnion arms and rotates on the pedestal, and a drum which is pivoted on the trunnion arms to allow it to be elevated and depressed.

The drum contains an automatic high-intensity carbon-arc lamp which is operated from a direct current power supply. At the rear of the drum is a metal reflector. At the front of the drum is a dome glass, an iris shutter for shutting

off the searchlight beam completely, and a high-speed sector vane shutter which may be operated locally or remotely.

Handles at the rear of the drum provide a means of swinging the searchlight in train and elevation to direct the beam of light.

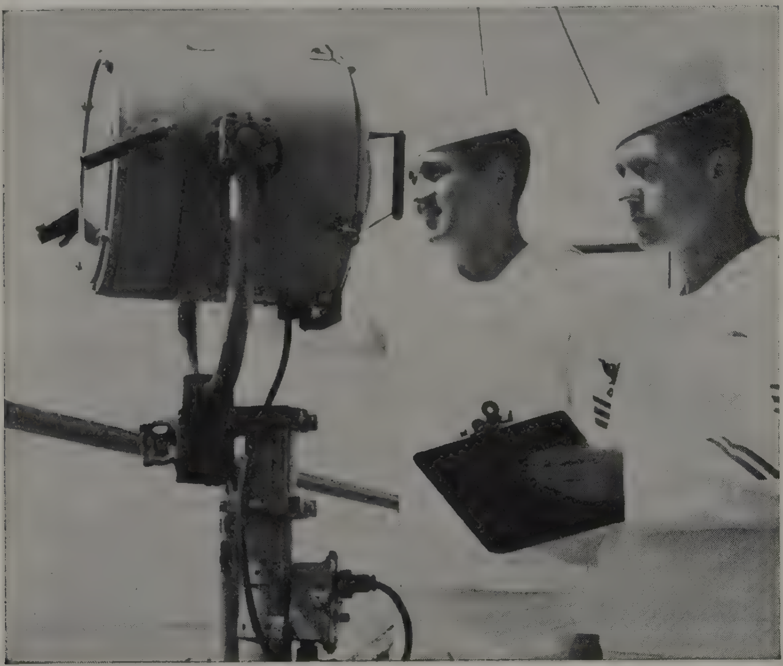


FIG. 7.3 THE 12-INCH SEARCHLIGHT IN USE. *Official U.S. Navy Photograph*

7.12. Nancy Facilities. *Nancy* is a system of visual communications using infrared light, which is visible only with the aid of equipment designed for this purpose (Fig. 7.4).

The most widely used nancy sending gear consists of a filter lens and hood for mounting on the standard Navy 12-inch searchlight. With this gear attached, the light is operated in the same manner as an ordinary communication searchlight. Under average conditions it has an effective range of 10,000 to 15,000 yards, depending on the type of receiver used. Other types of nancy beacons have been designed for recognition and reconnaissance as well as communication.

An infrared transmitting set is installed aboard many Navy ships. The transmitters may be operated as a steady source for "point of train" purposes, or they may be flashed in Morse code for signaling or recognition. Beacons of the infrared transmitting set are designed to show a beam through 360 degrees in bearing and from 20 degrees below the horizontal to zenith in elevation. The radiated signals cannot be detected by the unaided eye at dis-

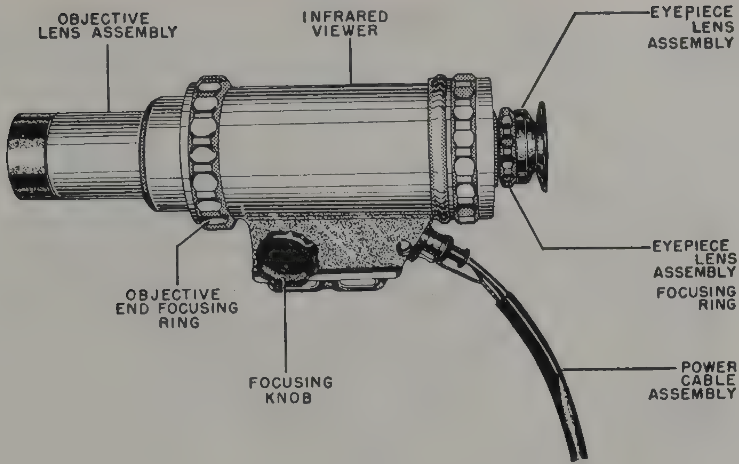


FIG. 7.4 A NANCY RECEIVER

tances greater than 400 yards. Beacons do not show any white lights; however, they are visible as dim red lights a few feet away.

A nancy receiver is required for all types of nancy signaling equipment. All image-forming receivers perform the same basic task. They gather up invisible rays and convert them into light that can be seen.

7.13. Flaghoist Signaling. The flags of a hoist are always read from the top down. When a signal is too long to fit on one halyard—when, in other words,

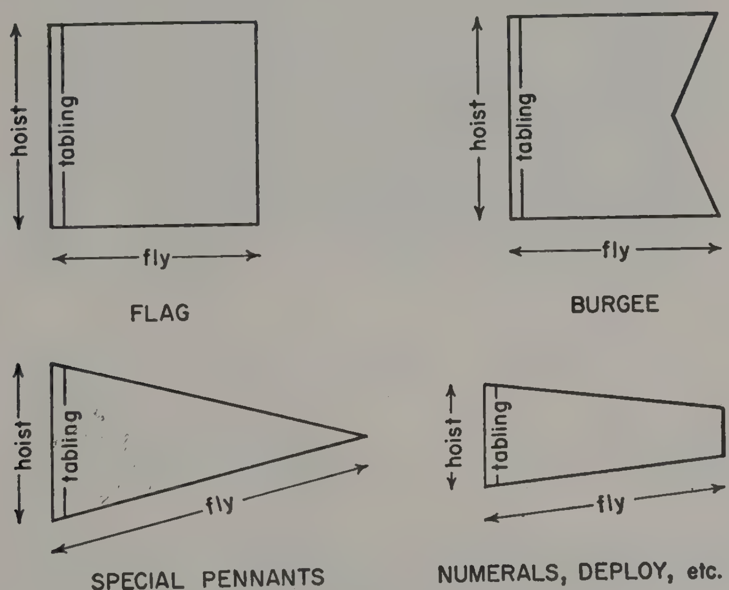


FIG. 7.5 TYPES OF FLAG, AND FLAG TERMS

more flags are required than can be made into a single hoist—the signal must be continued on another halyard. When a signal is broken into two or more hoists, it must be divided at points where there can be a natural space without affecting the meaning of the signal.

FIG. 7.6 MAKING UP THE HOIST. *Official U.S. Navy Photograph*

Flags are kept in flag bays as shown in Fig. 7.6. Such storage permits rapid makeup of the hoist. Figure 7.7 shows how the signal is hoisted as soon as each flag is attached.

Flags used on board ship are shown in color in the signal books. There are some differences between the flags used on merchant ships and those on men-of-war.

7.14. Other Signal Light Facilities. Men-of-war carry a number of lights which may be used to signal not only the status of the vessel according to the requirements of the Rules of the Road but for other purposes as well.

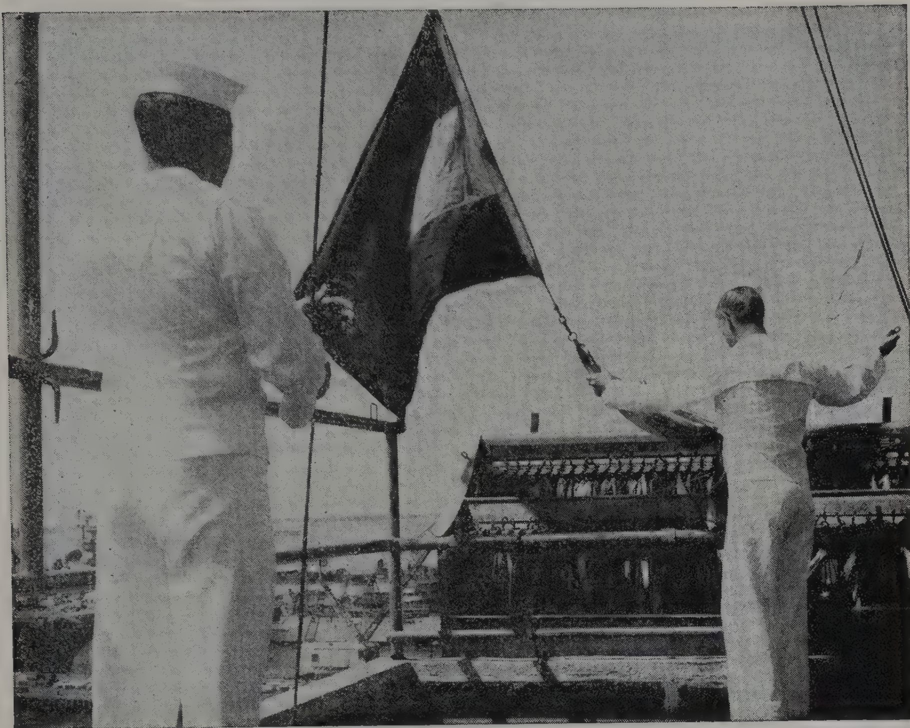


FIG. 7.7 HOISTING THE SIGNAL. *Official U.S. Navy Photograph*

The *boom lights, portable towing lights,* and minesweeper *polarity signal lights* (red and green) are energized from various local lighting circuits.

The masthead light, range light, side lights, white stern light, and permanent towing lights are usually controlled from the running light switch box on the bridge.

The signal and anchor light switch box on the bridge controls the following lights (when installed):

- Aircraft warning lights
- Forward and after anchor lights
- Blinker lights
- Breakdown and man overboard lights
- Minesweeping lights
- Underwater task lights
- Speed lights
- Station keeping lights
- Steering light
- Wake light

Due to the wide variety and uses of ships' lights, a brief description of the most important ones is included here:

Aircraft warning lights. One red light is installed at the truck of each mast and extends more than 25 feet above the highest point in the superstructure. Where it is impossible to locate this light so that it is visible from any location throughout 360 degrees of azimuth, two lights are installed.

Blinker lights. These lights are installed only on the signal yardarm, outboard, one port and one starboard. On ships with more than one mast they are located only on the forward yardarm. Screens are fitted at the base of these lights to prevent glare or reflections from interfering with navigation of the ship. Lights are operable from signal keys located on the bridge.

Boom lights. Boom lights are permanently installed on the outboard end of each boat boom and are energized from receptacles on the ship's service lighting system.

Breakdown and man-overboard (not under command) lights. These are mounted on brackets extending abaft, and offset from the mast or structure to permit all-around visibility insofar as practicable. To facilitate pulsating these lights as a "man-overboard" signal, the rotary snap switch in the signal light switch box which controls them is fitted with a crank handle.

Minesweeping lights. These lights are installed on all minesweepers or ships fitted to sweep mines to warn other ships to keep clear of the sweep gear. The signal consists of a triangular display of three 32-point green lights, one on each forward yardarm and on the foremast. Lights on the yardarm are at least 3 feet outboard of the mast and the light on the mast is at least 3 feet above the lights on the yardarms. The light on the mast is installed on a bracket extending forward of the mast and offset to ensure visibility ahead and astern.

Polarity signal lights. Two lights, one red and one green, are installed close together to each side of minesweepers to indicate polarity or direction of magnetic field. These lights are mounted to be visible from 20 degrees forward to 20 degrees abaft the beam on each side of the ship. They are pulsed by contacts in the minesweeping control panel.

Speed light. This light is installed in ships of escort ship (DE) size and larger to indicate the ships speed. It is located at the truck of the mast. If it is impracticable to locate this light so that it is visible throughout 360 degrees of azimuth, two lights are provided.

Stationkeeping lights. Two lights are installed on all minesweepers required to give sweep information at night. They are located in a vertical plane perpendicular to the keel so that accurate observations may be taken to aid bearings. These lights are mounted to be visible from 20 degrees forward of or 20 degrees abaft the beam on each side of the ship. If it is impossible to locate the lower light so that it can be seen on both sides of the ship, two lights are used, one on each side.

Steering light. This light is installed on specified ships and on ships where the pilothouse is more than 100 feet abaft the bow, unless structural interferences make use of this light impracticable. The light is located on the jackstaff or other centerline structure and is visible to the helmsman.

Stern light, blue. This light is installed near the stern of ships likely to be engaged in convoy operations. It is mounted to show throughout a total azimuth of 12 points—from astern to 6 points on each side of the ship.

Towing lights. Minesweepers, tugs, and other ships normally engaged in towing operations have permanently installed towing lights. Other ships have two

portable towing lights, each of which is equipped with sufficient cable and a plug connector to permit energizing these lights from the nearest lighting receptacle connector.

Underwater task lights. These lights are installed on all ships engaged in underwater operations, such as minesweepers. They consists of three lights in a vertical line one over the other not less than 6 feet apart. The highest and lowest of these lights is to be red, and the middle light is white. The red lights are the same fixtures as those used for breakdown and man-overboard lights, whenever practicable, and the switching is arranged accordingly.

Wake light. This light is installed on the flagstaff or after part of the ship to illuminate the wake, and is so mounted that no part of the ship is illuminated by it.

A type of signal light that does not fit into the foregoing categories is the *life preserver light.* Some ships also carry floating lanterns for marking waters at night when necessary.

In addition, aircraft carriers have a complex arrangement of night-flight operations lights installed. These consist of such lights as deck edge lights, homing lights, parking lights, take-off lights, etc.

7.15. Messages and Signals. In naval communications, a message is a formal type of communication; like a postal letter, it is addressed to a certain destination(s), has a *text,* and an *ending.* The address is known as the *heading.* The signal's form is abbreviated or modified. The signal (or sign) conveys a meaning nevertheless. Signals may be used in the process of transmitting messages; examples of this are message handling signals and call signs.

On Navy ships, the captain must authorize all communications sent from the ship—signals and messages. Some signals are made as a part of the ship's routine without this specific authorization in each case: an example of this is the running lights which are always turned on at sunset when under way. Messages, on the other hand, are authorized and released by the captain (or by other officers delegated this authority). Messages which have been released are delivered to either the ship's radio or visual station for transmittal. At either place call signs, internal handling instructions (signals) are added; the recipient is then "called" and the message is transmitted and receipted for. The ship maintains complete files of communications transmitted and received.

7.16. Sound Telecommunications. Sound signals are used routinely according to the Rules of the Road. Sound signals are also made by navigational aids, such as buoys, beacons, lighthouses, lightships, etc., as well as fog-bound ships. Sound may also be used in the maneuvering of ships (either as a supplement to visual signals or as a separate signal). It is important that signals in use for one purpose not be misinterpreted as being made for another purpose.

When signaling with sound in fog or listening to such signals, bear in mind:

Fog signals are heard at greatly varying distances. Under certain conditions of atmosphere, when an air fog signal is a combination of high and low tones, one of the tones may be inaudible. Occasionally a fog signal may be wholly inaudible in certain areas.

A fog bank may exist a short distance from a fog signaling station or ship and not be seen; therefore, the signal may not be sounded. Some fog signaling apparatus cannot be started immediately after signs of fog have been observed. Fog signals can sometimes be heard by fog lookouts in the eyes of the ship or aloft but may not be heard on deck or on the bridge.

Distress Communications

7.17. Distress Signals and Messages. Disaster or distress at sea is of paramount interest to all who sail the seas. Against the background of the vastness of the oceans must be considered the ability to: (1) communicate when in distress, (2) locate those in distress and (3) reach and assist those in distress.

Two international distress frequencies have been established: 500 kilocycles, primarily for radiotelegraph; and 2182 kilocycles, primarily for radiotelephone. The distress signal for radiotelegraph is the Morse code signal SOS (· · · – – – · · ·) and for radiotelephone, the word *MAYDAY*. These tell that the sending ship or aircraft is threatened by grave and imminent danger and requests immediate assistance.

Since most merchant ships have only one radio operator on board, they have an automatic alarm system that can be activated in the event of distress. A signal activates this alarm. It consists of 12 four-second dashes sent in one minute. The signal is sent before the distress message itself, permitting receiving operators to set their equipment on the distress frequency.

Ships receiving distress messages from a nearby ship acknowledge receipt, but only after first ascertaining that they will not interfere with messages from ships in a better position to render immediate assistance.

In addition to distress messages, *Urgency* and *Safety* messages are authorized for use on the international distress frequencies.

The urgency signal, *XXX* for radiotelegraph and *PAN* for radiotelephone, indicates that the calling station has a very urgent message to transmit about the safety of a ship, aircraft or other vehicle, or of some person on board or within sight. The urgency message has priority over all communications except distress messages.

The safety signal, *TTT* for radiotelegraph and *SAYCURITAY* for radiotelephone, indicates that the sending station has a message about safety of navigation or an important meteorological warning. This signal precedes reports of dangers to navigation and tropical storm messages sent to the approprite shore activity by reporting ships. It also precedes all traffic from shore stations concerning tropical storm and dangers to navigation.

All ships capable of doing so guard 500 kc. If necessary, ships may use this frequency to establish communications; however, they shift to a working frequency as soon as possible.

In addition the use of the foregoing international radio procedures, the Rules of the Road cover various methods of attracting attention for assistance.

7.18. What the Deck Officer Should Know About Communications. The precise procedure for sending and receipting for messages must always be followed by the deck officer in order to avoid confusion and dangerous communications delays. These procedures are described in many communications publications, some of which the deck officer must be familiar with and use.

The deck officer of a man-of-war should be able to use expertly the following signal publications:

1. The Allied Naval Signal Book
2. The International Code of Signals
3. Wartime Instructions for Merchant Ships

The deck officer of the merchant vessel uses:

1. The International Code of Signals
2. Wartime Instructions for Merchant Ships

Vessels may communicate in a number of ways using signals from these books. The signals are designed mainly for the various visual means, sound, or radiotelephone; radiotelegraph may also be used.

The International Code of Signals is published in several foreign language editions. With this signal book, language is no barrier to communications. For instance, a French freighter communicating with a U.S. destroyer would make up her message from the code of the French language edition of the International Code of Signals. The U.S. ship would look up the code meanings in her English language edition.

The Allied Naval Signal Book is used by U.S. men-of-war and other NATO men-of-war. The Wartime Instructions for Merchant Ships is used by ships in allied naval convoys. Each of the books contains types of signals not found in the others; messages or signals are sent, receipted for, and executed differently depending upon which system is in use. Signals from one book may, on occasion, be employed in conjunction with those of another book. The signal flags and pennants in each of the above books are basically those contained in the International Code of Signals with some additional flags and pennants in the other two books.

The deck officer should be familiar with the location and operation of all signal and communication equipment in the vicinity of the bridge. This includes the various signal (navigational) lights as well as the radiotelephone units, whistles, pyrotechnics, flags, pennants, and megaphones. It is necessary for the deck officers to reach this equipment instantly, day or night, and operate it correctly as the occasion demands. Larger ships have personnel to operate much of this equipment when ordered by the deck officer, but on smaller ships and on some merchant ships it is the deck officer himself who operates this gear.

8

Ground Tackle, Anchoring, and Mooring

Windlasses

A ship's windlass is designed primarily for handling anchor chain. The chain is guided over a fairlead and then around the capstan where it rides on a collar called a *wildcat*. This wildcat is essentially a sprocket designed to engage the links of the chain. The sprocket can be keyed to the capstan shaft and thus to the windlass motor, or it can be allowed to run free. A brake is also incorporated to control the wildcat when it is running free. Windlasses are arranged in many ways and combinations on various vessels, and are often provided with warping heads for handling line. There are four general classes, depending on the kind of drive: steam, electric, electric-hydraulic, and hand.

Anchors

When an old-fashioned anchor (Fig. 8.1) is let go in fairly deep water, it strikes the bottom crown first and immediately falls over until it rests on the end of the stock. From this position any drag on the chain to one side "cants" or capsizes it, pulling the stock down horizontally upon the bottom and pointing the flukes fair for biting. As the drag continues, the fluke is forced into the ground. If the anchor is well designed and enough scope of chain is used so that the pull is approximately parallel to the bottom, the heavier the pull, the deeper the fluke digs in. To obtain this effect a long enough scope of chain must be used so that the pull of the anchor will be approximately along the bottom. Use of too short a scope will lift the shank of the anchor and break out the fluke in a series of jumps.

Stockless anchors present an enormous advantage in ease of handling and stowing. On account of the absence of a stock, they can be hoisted directly into the hawse-pipe and stowed there ready for letting go quickly. Some features common to stockless anchors are:

1. The arms are pivoted upon the shank and can swing from 30 to 45 degrees on either side.
2. The palms are in the plane of the arms instead of at right angles to it.

3. As a result of this construction, both flukes should bite if either one does.
4. The arms carry a shoulder with a sharp edge at the crown which takes on the bottom and throws the arms downward to ensure the flukes biting.

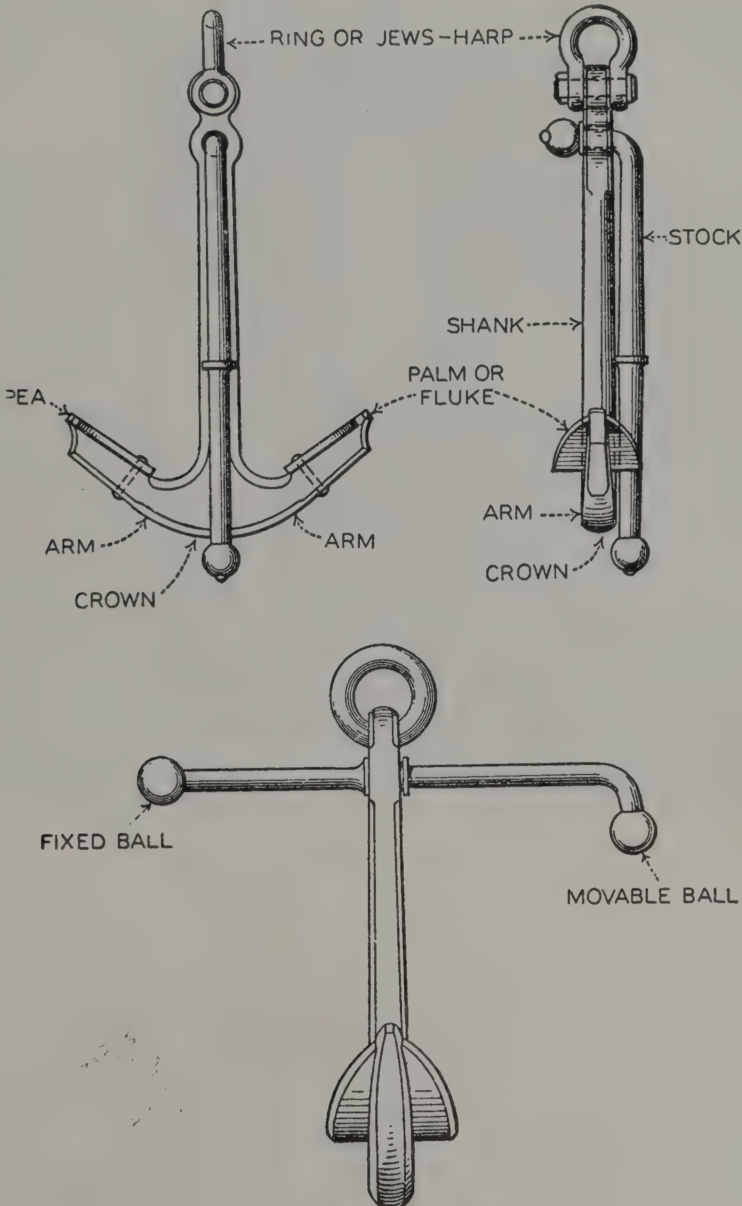


FIG. 8.1 OLD-FASHIONED ANCHOR

The stockless anchors most commonly encountered are the Baldt, the Dunn, or the Norfolk (Fig. 8.2) which is a Navy-manufactured anchor of the Dunn type. The Navy stockless is used on most men-of-war on account of its convenience in handling. Stockless anchors do not have as much holding power as an old-fashioned anchor of the same weight or of the same fluke area, which is a better measure of holding power than weight. With too short a scope of chain

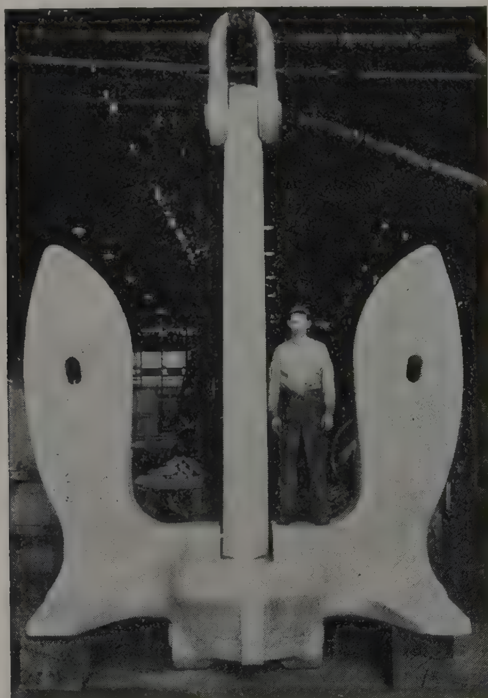


FIG. 8.2 LARGE NAVY STOCKLESS, 40,000-LB BOWER ANCHOR ON *U.S.S. MIDWAY* (CVA 41) CLASS

or even under a steady pull, a stockless anchor has a tendency to disengage its flukes by gradually turning over and rolling them out. It also has a tendency to clog or ball with mud in a muddy bottom. If this occurs and the anchor breaks out, the arms may pivot to an angle where it is impossible for the flukes to bite again. It can offer no resistance to dragging except its weight.

Many experiments have been made to overcome the foregoing disadvantages of the stockless anchor while preserving its handiness. Some of the best results obtained have been found in the design of the lightweight type of anchor (Fig. 8.3). This anchor has extra long and sharp flukes and an anti-rolling rod called *the stock* through the crown. Under a steady pull it shows a tendency to bury itself deeper in the bottom like the old-fashioned anchor and a disinclination to roll. In fact, difficulty in breaking it out before getting under way may be a disadvantage. It is claimed that this anchor has about three

times the holding power of an old-fashioned anchor of the same weight and about ten times the holding power of similar stockless anchors of the conventional types. The stock through the crown does not interfere with stowing it in the hawse pipe.

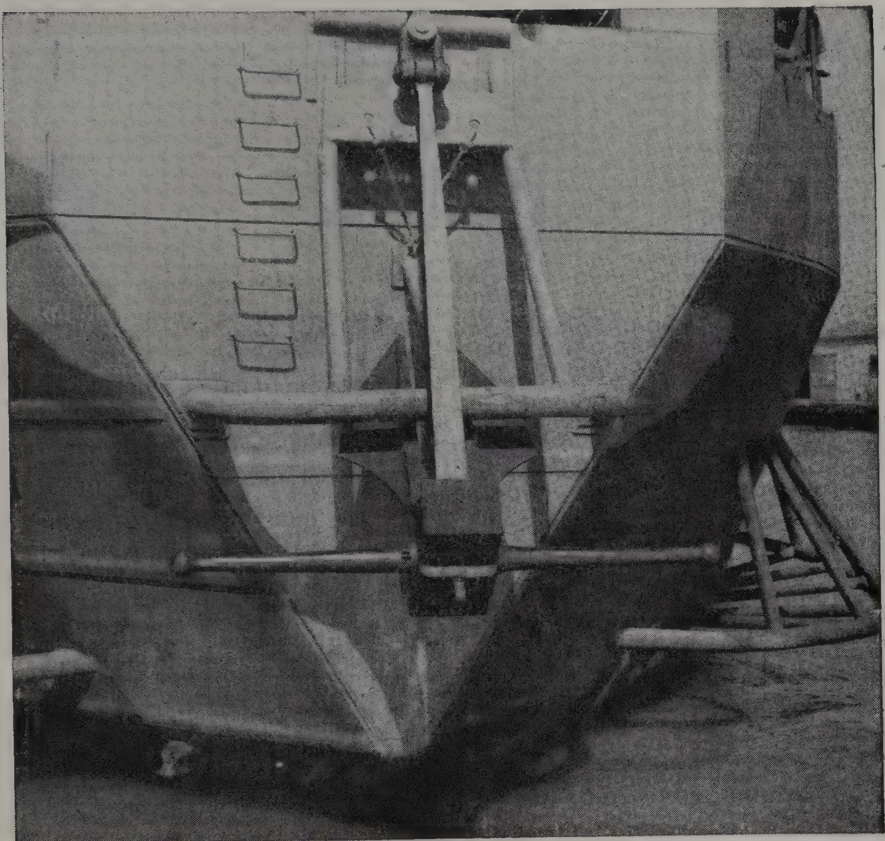


FIG. 8.3 LIGHT-WEIGHT TYPE (LWT) NAVY ANCHOR. LST STERN ANCHOR, 3,000-LB SIZE. *Official U.S. Navy Photograph*

8.1. Anchor Gear. *Chain Cable.* Chain is made to Navy and commercial link standard dimensions which are the same, 6 wire diameters long by 3.6 diameters wide. Anchor chains furnished in time of war are of all types: die-lock, forged and welded, stud-link, and cast steel. Die-lock and high-strength welded steel types of chain are considered standard and will replace other types. (See Fig. 8.4.)

Connecting Shackles. Detachable links are used for connecting the shots of anchor chain. They have replaced the old Navy standard U-shaped shackles and also the Kenter connecting shackle. Detachable links of commercial design are also furnished for use with cast-steel chain. (See Fig. 8.5.)

Bending Shackles. Bending shackles for use with cast steel chain (conforming to American Bureau of Shipping requirements) and with die-lock chain are used for attaching the anchor to the chain cable. (See Fig. 8.6.)

Mooring Swivels. Forged steel swivels with two detachable links attached at each end are for use in mooring. (See Fig. 8.7.)

Housing Chain Stoppers. Navy standard housing chain stoppers are used for holding the anchor taut in the hawse pipe or for riding to an anchor or holding the anchors when the anchor chain is disconnected for any reason. The large chain stopper wrenches are used for equalizing the strain on the stoppers when riding to an anchor with more than one stopper in use and for securing the anchor in a hawse pipe. (See Fig. 8.8.)

FIG. 8.4 SWIVEL-SHOT, LARGE-CHAIN, 3½" HEAVY-DUTY DIELOCK. *Official U.S. Navy Photograph*

Mooring Shackles. Forged-steel shackles are used for attaching the anchor chain to mooring buoys. An additional special lightweight mooring shackle, not possessing the full strength of the anchor cable, is used for some ships.

Shackle Tool Sets. Tool sets including spare taper pins and locking plugs are provided for use in assembling and disassembling detachable links.

Clear Hawse Pendants. A wire rope pendant, 5 to 15 fathoms long, fitted with a thimble at one end and a thimble length of open link chain and a pelican hook at the other end, is used in clearing a hawse which has been fouled by the anchor cables.

Dip Ropes. A fiber rope pendant fitted at one end with a thimble and a dip shackle large enough to engage a link of the anchor chain is provided for use in mooring or clearing a hawse.

Outboard Swivel Shots. Standard outboard swivel shots consisting of detachable links, regular chain links, a swivel, end link, and bending shackle are fitted on most vessels to attach the anchor cable to the anchor. These vary in length up to approximately 5 fathoms and are also termed bending shots. The taper pin in the detachable link in the outboard swivel shot is additionally secured with a wire-locking clip.

Chain Cable Jacks. A cable jack consisting of a lever mounted on an axle and two wheels is used for handling anchor chain of 2¾-inch size and larger. An anchor bar of the pinch-point crowbar type is used for smaller sized chain.

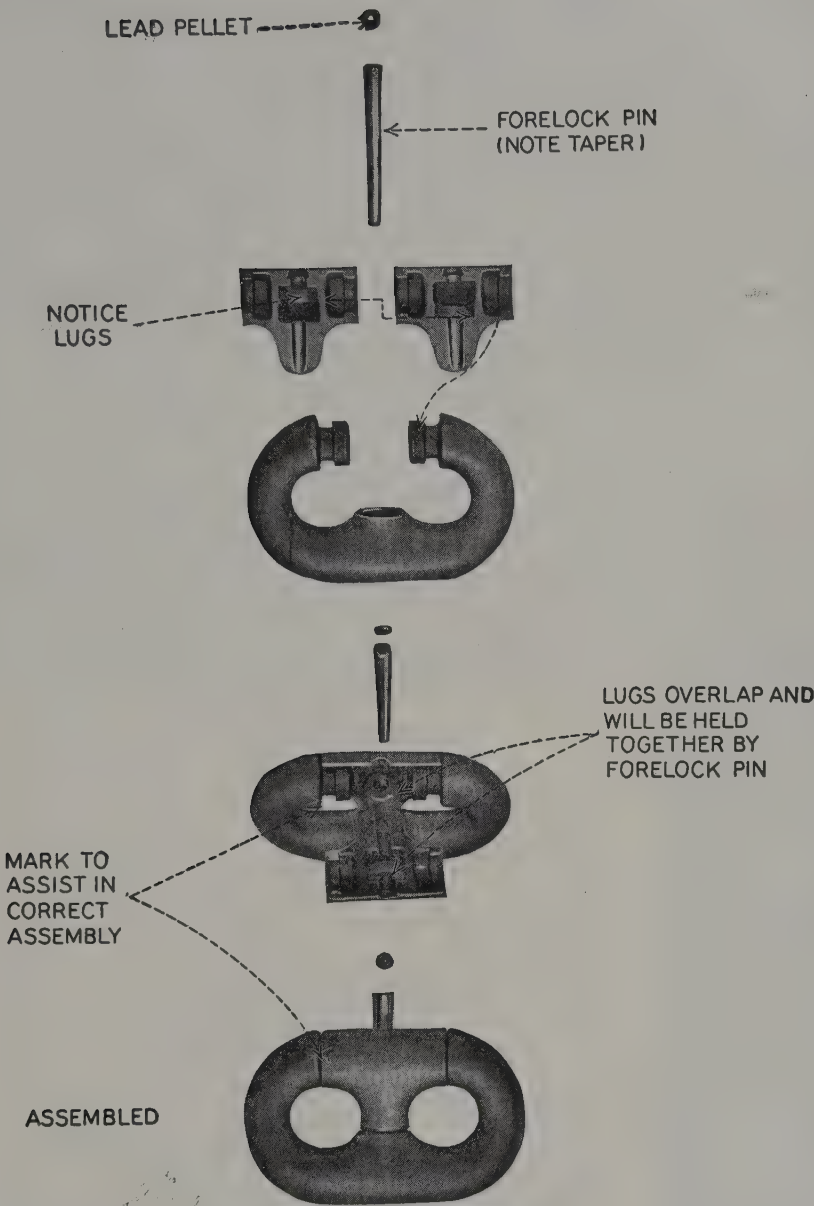


FIG. 8.5 DETACHABLE LINK

FIG. 8.6 LARGE-SIZED BENDING SHACKLE FOR 3½" HEAVY-DUTY DIELOCK CHAIN. *Official U.S. Navy Photograph*

Mooring Hooks. These hooks are used on destroyers and smaller ships for facilitating mooring to a buoy.

8.2. Die Lock and High-Strength Welded Steel Stud-Link Chain. Die-lock and high-strength welded steel chain are standard. Cast-steel, die-lock, and high-strength welded steel chain are capable of withstanding great shock, have uniform dimensions, and the elastic limit of the links is high.

FIG. 8.7 MOORING SWIVEL, LARGE SIZE. *Official U.S. Navy Photograph*

Under the usual service conditions, the links of these types of chain do not stretch or become deformed, and the chains will operate smoothly over the wildcat during the period of their entire useful life. Cast-steel chain can be distinguished by the fact that the studs are solid and an integral part of the links, and each common link in the shot is identical. High-strength welded steel chain in some types is made up with alternate solid-forged links having integral studs. Every other link has the stud welded in place. In one type of high-strength, welded steel chain which is constructed of alternate solid-forged and welded links each welded link is reforged after welding, and the entire chain has the appearance of being made of solid-forged (or cast-steel) links with integral studs throughout. The studs of the die-lock chain are also an integral part of the link; they are, however, split through the middle. The fact that the studs of cast-steel, die-lock, and high-strength welded steel chain cannot fall out is a great advantage because this eliminates the danger of the chain kinking and the pounding of links on adjacent links.

Die-lock links are made of two-forged pieces, both roughly U-shaped. Two stems of one piece contain a

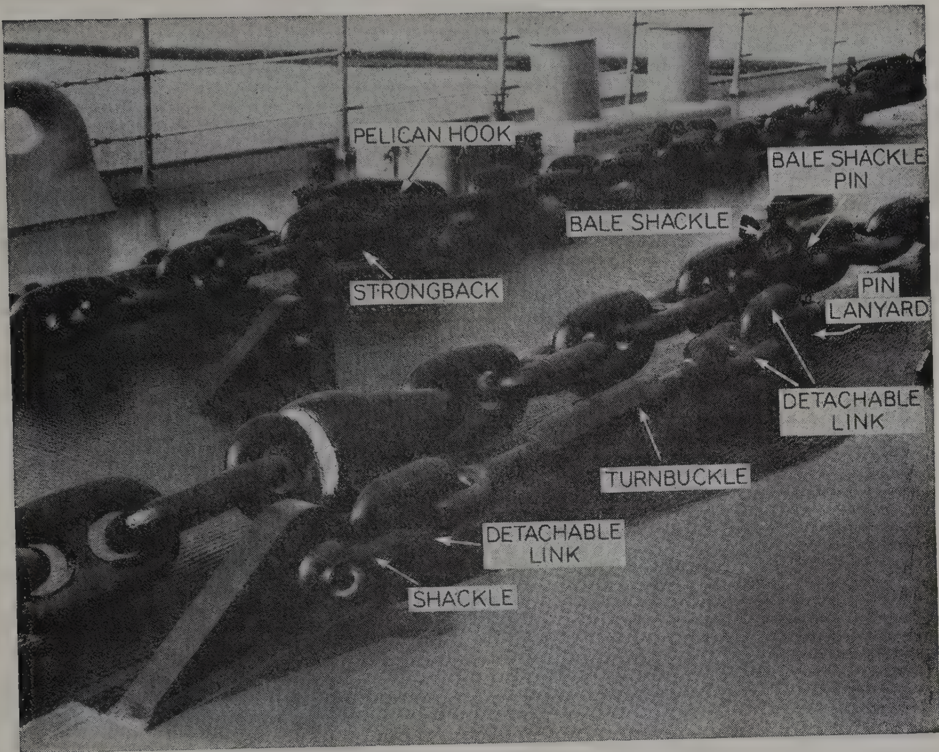


FIG. 8.8 CHAIN STOPPER. *Official U.S. Navy Photograph*

series of paralleled indentations, giving them the appearance of screws. The socket piece has holes at each end of the U. In joining the two pieces to form a link, the pierced socket section is heated, then the stems of the other section are thrust into the holes. The socket section is then pounded with a drop hammer, forcing its material around the indentations in the stems in die blocks.

8.3. Chain Identification Marks. Each shot of the chain usually bears a serial number that is stamped, cut, or cast on the inner side of the end links of each shot at the time of manufacture. In the case of cast-steel chain this number is preceded by the letters C.S. If an end link is lost or removed from a shot, this identification number should be cut or stamped on the side of the new end link of the altered shot. Cast-steel and some types of high-strength welded steel chain have these markings on the studs of alternate links only.

Each shot of die-lock chain has a serial number and date of manufacture stamped on the inner side of the end links. The studs of such chains are marked "U.S.N." on one side of the stud and the wire diameter of the chain on the other side.

8.4. Anchor Identification Marks. Every anchor, except small boat anchors and lightweight type (LWT) anchors 100 pounds and less in weight, when pur-

chased for Navy use and before delivery to respective naval shipyards, has cast or cut in its crown a serial number. This serial number should not be confused with the weight number which also appears on the anchor. It is the practice on stock or old-fashioned anchors for one side of the crown to be marked with the initials of the inspector, the name of the manufacturer or commercial name of the anchor, and the serial number of the anchor. In the case of lightweight type anchors, this legend may appear on the shank.

On the opposite side of the crown the weight of the anchor in pounds, the year of fabrication, and "U.S. Navy" are cast, stamped, or cut by the manufacturer. The same practice is adhered to in regard to the stockless anchors, except that the markings appear on each side of the flat of the crown.

Ground Tackle

Ground tackle consists of all of the anchors and anchor chain in a vessel as well as the necessary handling gear. The sizes, weights, and amount supplied to vessels in service are determined after consideration of the characteristics and operating conditions of the vessels and of past experience.

8.5. Navy Type Detachable Link (Fig. 8.5). The Navy detachable link has been adopted as standard for use as a connecting link for joining shots of anchor chain on naval vessels. It has replaced the old U-shaped connecting shackle and also the Kenter connecting shackle which consisted of two interlocking half sections held in place by a stud and a taper locking pin.

The Navy Type Detachable Link consists of a C-shaped link with two coupling plates which form one side and the stud of the link and a taper pin which holds the parts together and is locked in place at the large end by a lead plug.

When assembling detachable links, care should be taken to ensure that the parts are correctly matched. Detachable link parts are not interchangeable, and matching numbers are stamped on the C-link and on each coupling plate to enable proper identification for correct assembly. The matching surfaces should be slushed with a mixture of 40 percent white lead and 60 percent tallow by volume prior to final assembly. Vessels outfitted with cast-steel anchor chain are furnished detachable links of Navy and also commercial manufacture, such as E-Z joining links (Naco), Esco connecting links, and riveted (Naco) connection links.

8.6. Riding and Housing Chain Stoppers (Fig. 8.8). Riding and housing chain stoppers consists of a turnbuckle inserted in a short section of chain, a slip or pelican hook attached to one end of the chain, and a shackle at the other end. The stopper is secured by the shackle to a permanent pad on the vessel's deck. When in use, it is attached to the anchor chain of the ship by straddling a link with the tongue and strong back of the pelican hook, a certain number of standard chain stoppers are supplied to naval vessels as a part of their equipment. It is the latest practice in the case of destroyers to fit

one stopper in the way of each chain cable. On auxiliary vessels and vessels of merchant type, two in the way of each chain cable are fitted if it is practicable to do so. On destroyers, the stopper is made of the same strength as the anchor chain. Because the windlass on these vessels has only one wildcat, it is intended that one chain shall be held by the windlass and the other by its chain stopper. In the case of other vessels, chain stoppers are furnished of such size that the strength of each is equal to about 40 percent of the chain cable with which it is used. The stoppers should not be solely relied upon for holding the anchor. Upon anchoring, the wildcat brake band should first be set up tight, and the stoppers then used to back up the brake band. The wildcat should then be disconnected from the engine.

8.7. Purposes of Chain Stoppers. The purposes for which chain stoppers may be used are as follows:

1. To ride to when at anchor, in addition to the use of the brake band on the windlass.
2. For letting go the anchor more quickly than can be done by the brake band.
3. As an emergency fitting in case the brake band of the windlass should get out of order.
4. To hold a chain from running out, while it is being taken off the wildcat, to permit another chain to be put on for heaving in. On destroyers, to hold a chain being bitted or unbitted or brought to the windlass.
5. To hold the anchors taut in the hawse pipes when housed, except in cases where the end of the anchor shank or the anchor shackle projects above the deck line (nonstandard).
6. To hold an anchor chain when disconnected for the purpose of attaching the mooring swivel. Lashing can be resorted to in addition.

Anchoring

Letting go a single anchor is perhaps the simplest method of securing a ship to the bottom, and if the holding ground is good she should ride easily in bad weather provided ample scope of chain is used. The disadvantages are that in a strong current or in a gale she may sheer considerably, and also when a ship is anchored, it swings to the combined effects of the wind and current. Therefore it is necessary to have an unobstructed area equal to a circle whose radius is the length of the ship plus the scope of chain used. If, for some reason, the anchorage does not afford such an area, the ship must be moored.

8.8. Letting Go. In modern ships with heavy ground tackle, the anchors are commonly housed in the hawse pipe and secured by chain stoppers which engage the chain by a slip or "pelican" hook.

To ensure that an anchor will let go *immediately* after the housing chain stopper is released, prepare as follows: connect up windlass wildcat, slack and release the outboard housing chain stopper and then engage the pelican hook

of this housing chain stopper to the first horizontal chain link abaft the link previously engaged, release friction brake, heave in until windlass wildcat has the strain, cast off the after chain stopper(s), walk out anchor until the outboard housing chain stopper has the strain and there is one link of slack chain abaft stopper, set up friction brake lightly to prevent the slack chain from going into the chain locker, and disconnect windlass wildcat.

If the drift between the hawse pipe and the chain locker is considerable, it is well to rouse up a few links of chain and lighten the slack forward to a point just abaft the stopper. Care must be taken that all is clear below decks and in the chain locker.

To let go, the bale shackle pin is pulled out, and then the bale shackle of the chain stopper is knocked off the pelican hook with a sledge.

Always bear in mind that the anchors may be unexpectedly required when on soundings, in narrow channels, restricted waters, or working around docks, etc. If they are ready for *instant* use, they may save worry and trouble. The anchor should always be let go with the ship moving slowly either ahead or astern, to avoid paying the chain down on top of the anchor.

8.9. Anchoring in Deep Water. Where it becomes necessary to anchor in very deep water, it is absolutely essential that the ship should be going dead slow. As the anchorage is approached at very slow speed, the usual practice is to walk out the anchor to within 5 to 20 fathoms from the bottom at the proposed anchorage, fasten the stopper to the chain, and disengage the windlass, making the anchor ready for "letting go," and then let go. Maintain only enough headway to avoid paying the chain down on top of the anchor. The details of handling the windlass for anchoring in this way will vary with the type of windlass used, but it will be found that even where the ship is dead in the water and where the anchor is let go with only a few fathoms of drop, the weight of the chain alone will cause it to run out violently. In extreme cases, where the depths run to 40 and 50 fathoms, it may be advisable not to "let go" but to "walk out" the chain by the windlass engine until the anchor is on the bottom and the necessary scope of chain out.

8.10. Anchoring at High Speed. If obliged to let go at a higher speed, or if for any reason it does not seem safe to check the ship with a short scope, the chain should be allowed to run until the ship loses her way sufficiently to make it safe to snub her. There is no great harm in running out 75 or even 90 fathoms of chain and afterward heaving in to a shorter scope; and it should be remembered that, in cases where the headway has to be checked by bringing up on the chain, the danger is less with a long scope than with a short one.

The danger connected with letting go while under considerable headway is often overlooked because the damage resulting does not necessarily show itself at once. The excessive strain may distort and weaken the links of the chain without actually parting them. The result is that the chain may give way at some time under a comparatively moderate stress. The practice of reducing the ship's headway by means of her ground tackle may introduce strains sufficient

to cause fracture and will in any event be very apt to strain the chain beyond its maximum safe load equal to the proof load.

8.11. Scope of Chain for Maximum Holding. The scopes given in the following table are the "optimum" scopes for maximum holding. If longer scopes are used, the chain may be stressed beyond its safe service working load; if shorter scopes are used, the anchor will tend to drag before developing the full safe load on the chain. These figures apply substantially, regardless of the size of the ship, provided the ship is furnished with a properly balanced outfit of ground tackle and is given a safety factor of 4 on the ultimate strength of the chain. The scopes shown for the greatest depths could be obtained only by bending additional shots to the standard lengths of chain cable.

SCOPE TABLE

Chains	Depth in fathoms (outboard lip of hawse pipe to bottom)									
	5	7½	10	15	20	25	30	35	40	45
Cast-steel chain (fathoms).....	64	78	91	110	127	142	155	166	178	188
Die-lock N.E. steel chain or 1.25 manganese steel chain (fathoms)................	74	90	104	127	146	164	178	192	204	216
Die-lock nickel steel chain (fathoms)................	78	95	109	133	154	174	188	202	216	228

It is a common rule under ordinary circumstances to use a length of chain equal to five to seven times the depth of the water. This is satisfactory in depths of water not exceeding 18 fathoms. This amount of chain is perhaps enough for a ship riding steadily and without any great tension on her cable. On the other hand, if conditions necessitate, the chain should be veered when anchored in shallow depths to the maximum indicated in the scope table.

If greater holding power than that given by one anchor with the scope of chain shown in the table is necessary, it is better practice to drop a second anchor even with moderate scope of its chain than to rely upon the one anchor with a longer scope. Of course, in the case of extreme necessity when the greatest holding power is necessary, all anchors should be dropped and the chain veered the greatest possible scope. If there is ample sea room, it would be better to reduce the scope to the amounts shown in the table and accept the possibility of dragging anchor rather than risk breaking the chain.

8.12. Anchor Chain Marking. *1. Painting.* Anchor chain shall be painted as follows to serve to identify the length of cable paid out:

One link on each side of the 15-fathom detachable link shall be painted white.

Two links on each side of the 30-fathom detachable link shall be painted white.

Three links on each side of the 45-fathom detachable link shall be painted white, etc.

Detachable links shall be painted as follows: 15-fathom D link, red; 30-fathom D link, white; 45-fathom D link, blue; 60-fathom D link, red, etc.

The exception to the foregoing is that all of the links in the last 15-fathom shot inboard shall be painted red, and all of the links in the next adjoining 15-fathom shot shall be painted yellow.

On auxiliary vessels where the distance between hawse pipe and wildcat is short, and consequently, only a short time is available for pointing the chain while it is being heaved in, it may be desirable to limit the number of painted links on each side of the detachable link to one.

2. Marking. Anchor chain may be marked by turns of wire on the studs of certain links. The number of links counting away from the detachable link is used as a marker for that shot.

The first link at each side of the 15-fathom detachable link has one turn of wire around the stud.

The second link at each side of the 30-fathom detachable link has two turns of wire around the stud.

The third link at each side of the 45-fathom detachable link has three turns of wire around the stud, etc.

8.13. Merchant Service Markings

15 fathoms, one turn of wire on first stud from each side of shackle.
30 fathoms, two turns of wire on second stud from each side of shackle.
45 fathoms, three turns of wire on third stud from each side of shackle.
60 fathoms, four turns of wire on fourth stud from each side of shackle.
75 fathoms, five turns of wire on fifth stud from each side of shackle.
90 fathoms, six turns of wire on sixth stud from each side of shackle.

A system which is gaining rapid popularity with merchant men is to adopt features of the Naval system of marking anchor chain. That is, to paint the links white, between the marked stud links.

The markings run thus: (this is in addition to the turns of wire)
15 fathoms, white paint on half the stud link on either side of shackle.
30 fathoms, white paint on 1½ links on each side of shackle.
45 fathoms, white paint on 2½ links on each side of shackle.
60 fathoms, white paint on 3½ links on each side of shackle.
75 fathoms, white paint on 4½ links on each side of shackle.
90 fathoms, white paint on 5½ links on each side of shackle.

8.14. Care to Prevent Bending Chain. Anchor chain when being used should not be subjected to short bends. Care should be taken to ensure whenever possible that anchor chain is not subjected to bending, such as may occur when the cable is lying across a vessel's stem, when a vessel is riding to a single anchor in a strong wind or current and the vessel is *"horsing"* or tacking back and forth, or when the cable is rove through a buoy ring or passed over a bolster of small radius. Chain is not as strong when subjected to such trans-

verse bending. This is especially true in the case of die-lock detachable links, and therefore extra precaution should be taken to prevent subjecting these links to transverse bending.

8.15. Care of Ground Tackle by Ship's Force. Anchors, chains, and appendages should be kept in good condition by the ship's force. The chain cables should be overhauled whenever necessary and precautions taken to see that the various shots are properly marked and in good order. As the chain comes in when getting under way, each link should be examined for cracks and for other defects.

8.16. Periodical Inspection and Painting of Ground Tackle in Service by Ship's Force. Once each quarter and more often if necessary, all anchor cables in sizes up to and including 1½ inches should be ranged on deck and examined throughout their entire length. If necessary, they should be scaled and cleaned of rust and other foreign matter. Detachable links should be disassembled and examined for excess wear or corrosion, and, where conditions warrant, the links should be replaced by new ones. Before reassembly, the links should be white-leaded. The detachable link located in the outboard swivel shot is fitted with a corrosion-resisting steel locking wire which serves to hold the taper pin in position. Disassembly of this link requires the removal and probable destruction of the locking wire, and the availability of replacement wire of the same type should be established prior to removal for inspection. Shackle bolts, locking pins, and swivels should be carefully examined and put in order, and such parts as require it should be coated with the special black chain paint furnished vessels for this purpose. In cold weather it is desirable to apply some heat to counteract the natural thickening of this paint. This may be done by an immersion electric heater or a steam coil. Experience has also shown that, when left standing for a considerable period, the turpentine substitute may evaporate to a considerable extent, with the resultant thickening of the paint. Vessels receiving anchor chain coated with green paint from stores should leave this coating intact and cover it with black chain paint.

Chain of sizes in excess of 1½-inch wire diameter should be overhauled, wirebrushed, and placed in a good state of preservation as often as is necessary. At least once each 18 months all anchor chain cable, regardless of size, including shackles and shackle pins, and detachable links, should be examined, overhauled, and placed in a good state of preservation. Shackles and shackle pins and detachable links should be refitted and greased or white-leaded, and identification marks should be restored if necessary. To distribute the wear uniformly throughout the entire length of the cable the shots should be shifted to a new position as necessary. In the case of vessels having cable the shots of which are connected with detachable links, 40- or 45-fathom shots may be shifted to any position in the cable which, in the Commanding Officer's opinion, will tend to distribute the wear evenly throughout the cable. In the case of vessels the shots in the cables of which are connected with U-shaped shackles, the 40-fathom shot should remain the first shot inboard of the outboard swivel

shot regardless of wear. If serious defects are discovered during this overhaul of the anchor cables, the defective shots should be shifted to the bitter end of the cable until replacement can be accomplished. See the *Bureau of Ships Manual* for complete instructions for maintaining anchor equipment as well as for instructions on securing the bitter end of the anchor chain to the ship's structure.

8.17. Weighing Anchor. In heaving in, the windlass and chain can be relieved of considerable strain by a judicious use of the engines and rudder. To do this, the forecastle detail must keep the bridge fully informed as to how the chain "tends"; whether the chain is "taut" or "slack"; when the anchor is at "short stay"; when the chain is "up and down"; and when the anchor is "aweigh." As the anchor is hove in, the report is made to the bridge, "Anchor in sight, sir," "Clear or foul anchor," as the case may be; "Anchor clear of the water, sir," "Anchor is up, sir." The Captain will then direct, "Secure the anchor" or "Get the anchor ready for letting go."

In case the chain tends across the bow, it may be cleared by stopping the windlass and going astern.

8.18. Foul Anchor. While modern double-fluke anchors are much less likely to foul than the old type, they occasionally give trouble in this way. A ship whose anchors house in the hawse pipes may be greatly embarrassed by the lack of facilities for lifting the anchor to a point where it can be hung securely and where the chain can be handled conveniently. As a rule in such cases, put a chain stopper on the chain, disengage the wildcat and let anchor go, engage wildcat, and heave in.

Under conditions such that the anchor may be expected to foul, it is a good rule to "sight" it frequently; and indeed this is advisable under any conditions when a ship remains at single anchor for a long time. It is especially important if bad weather is found to be approaching after lying for some time under circumstances which make it probable that the anchor may be foul. For sighting (the anchor may be weighed and another anchor let go when the chain of the first one is "up and down."

An anchor sometimes becomes so well dug in or so fouled in rock or coral that it cannot be raised in a normal manner. Here the use of a wire strap around the crown may be needed. Anchorage charts often reveal locations where anchors have been lost, such as St. George's Channel, Bermuda. If necessary to anchor there it might be wise to consider fitting a crown strap and a buoyed work wire to the anchor before letting go. An anchor that has been lost with some chain attached can usually be recovered by the use of grapnels or an *anchor hawk*.

8.19. Riding to a Single Anchor. A vessel at single anchor in a strong tideway is likely to sheer considerably. This movement brings the current first on one side and then on the other and drives the vessel across the stream until brought up by her chain often with a violent shock. This may be prevented in a great measure by holding her with a steady sheer away from her anchor, by

putting the rudder over as far as may be necessary, and keeping it there. The stern is driven over to one side and she is canted across the current and held there.

A ship is never in greater danger of dragging her anchor or parting her cable than when driving down with a slack chain, broadside on or partially so to wind or tide. Such a situation may of necessity arise in anchoring or may come about in sheering, as described above. It frequently happens in squally weather, where a ship swings in one direction during a lull just in time to be caught by a strong squall on the beam and be driven bodily off. It may be brought up with the chain taut across the stem.

In lying at an anchorage where such situations may arise, the greatest watchfulness should be exercised. Steam must be kept on the steering engine, a man must be at the wheel, an ample scope of chain should be veered, and a second anchor should always be ready for letting go at a moment's notice, even though there seems no chance of its being needed.

When the conditions are such that there is a possibility of dragging the anchor, a lookout should be posted to ensure instant notice if she begins to drag. The drift lead is useful, though not always to be trusted. This is a heavy lead kept on the bottom with its line made fast to some place well forward convenient for observation and left hanging with considerable slack. If the ship drags, the line tautens and tends ahead.

So long as a ship is fairly steady, a drift lead will usually give notice in case of dragging, but if she sheers about considerably, it cannot be relied upon. The farther forward it is used, the better, because the bow moves much less than the stern in sheering.

Good bearings of objects on shore are more reliable than the drift lead, and a range is best of all. Both of these are less trustworthy when the ship is sheering about than when she is steady because a range will open out when the ship swings and may seem to indicate that she is dragging. Its indications may be checked by watching the heading. Radar ranges to fixed objects ashore may also be used to detect dragging.

There are times when unexpected and unusual swells, seas, and currents set in toward an anchorage. In such cases the only thing to do is to get up steam promptly and shift to a safe anchorage or stand out to sea. The sailing directions should always be carefully read and every effort made to obtain the latest weather reports. There are also times when nearby ships will swing in opposite directions when there is little current or wind. In such cases each ship may heave in sufficient chain to avoid fouling; at other times one or more boats placed at the stern will exert sufficient power to push the ships clear or hasten their swing.

It is always advisable to keep a detachable link on deck where it can be reached conveniently for slipping suddenly if an emergency arises and to be sure that the pins can be driven out without difficulty. Tools for unshackling should be kept in a convenient place and never removed. A buoy and a buoy-

rope at hand complete the preparations for slipping at short notice. In an exposed anchorage subject to sudden gales, these precautions are, of course, especially important.

If a vessel or other danger is seen drifting down upon you when lying at anchor in a tideway, by giving the ship a cant with the rudder thus bringing the current on the bow, and veering the anchor chain roundly, you may sheer well over across the tide and probably be clear of danger.

If an anchor is known to have dragged in a clay bottom, it should be picked up as quickly as possible; for it is certain to be "shod" (balled in mud) and to have lost much of its proper holding power. In letting go where the bottom is of this kind, it is important to give a good scope in the very beginning to prevent even the little dragging that is commonly to be expected as the anchor digs down to get its hold.

The plan of bending two cables together to obtain a "long scope" is not recommended if such a scope would result in exceeding the safe limit in the scope table. The fact must not be overlooked, however, that a defective link or shackle may result in disaster where a single cable is in use, and this may make it wise to let go a second anchor in cases where no chances can be taken. The vessel would then be moored.

Mooring

A ship is moored when she has two anchors down at a considerable distance apart and with such scope of chain on each that she is held with her bow approximately midway between them. A ship moored requires an unobstructed area reduced to a circle with a radius only slightly larger than the length of the ship.

8.20. Reasons for Mooring. There are two basic reasons for mooring: (1) To reduce the radius of the circle of the unobstructed area in which the ship will swing, by using an ordinary moor. Since it is desirable to make a taut moor under these conditions, the anchors should be so placed with respect to any current that a straight line connecting the two anchors would be parallel to the direction of current flow. (2) To snub the bow of a ship and prevent it from sheering in a current, gale, or hurricane, by using a bridle or hammerlock moor. Under these conditions, it is necessary to use a slack moor so the angle between the chains is about 90 degrees, and to place the anchors so that a straight line joining them would be perpendicular to the direction of current flow or expected wind.

8.21. The Ordinary Moor. In the ordinary moor the ship stands against the current (wind) to the proper position and lets go the first anchor which must always be the riding (upstream) anchor at that time. She veers on the riding chain, carefully laying out the chain so as to keep it taut and tending ahead as she drops down with the current (wind) to the position for letting go the lee or downstream anchor. When that position is reached, the second anchor

is let go. She now veers on the lee chain and heaves in on the riding chain, taking care to lay the lee chain out properly until she is riding midway between both anchors with the desired scope of chain to each.

A mooring swivel is frequently used to prevent the anchor chains from fouling one another when a moored ship swings to the wind or current. When the mooring swivel is used, it is impossible to veer both chains.

8.22. The Bridle or Hammerlock Moor. In riding out a gale or hurricane, a vessel will often sheer violently back and forth across the wind (Fig. 8.9) and here the rudder has little effect in holding her with a steady sheer. This tacking back and forth is often called "horsing." Violent horsing can be cut in half by dropping a second anchor under foot with minimum scope out to it to act as a snubber, but even such reduced horsing may become excessive in a violent storm. In such cases, it is well to pick up the second anchor and redrop it at one extreme reach of a sheer, still using only a short scope, and then ride to this bridle (Fig. 8.10). The two chains will now work together to snub the bow and hold it steady. The "horsing" will be almost completely eliminated and the main engines can be used with precision to offset the greater portion of the wind. The wind velocity—ship speed curves (Fig. 8.12) are of value here. Should the wind be from a hurricane or typhoon, and should the bottom be sand or mud, it is sometimes feasible to permit the short-scope anchor to drag around as the wind veers or backs so that the open "X" or "V" of the bridle moor always faces the wind (Fig. 8.11). This bridle moor can be used whether the chains lead from the hawse in an open "V" or whether they cross the stem in an "X" (Fig. 8.12). Either position is satisfactory, but with pre-planning as the hurricane approaches, it is naturally preferable to figure out which anchor should be used as the riding (long-scope) anchor in order to ride out the entire wind shift with an open "V" hawse as the short-scope anchor drags around.

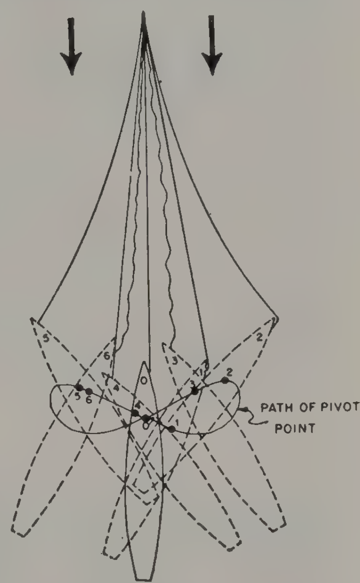


FIG. 8.9 HORSING MOVEMENT OF A SHIP RIDING TO A SINGLE ANCHOR. This diagram shows the violent figure-eight horsing motion of a ship riding with a long scope of chain out to a single anchor during a high wind.

8.23. Length of Scope When Moored to a Buoy. The need for veering chain when moored to a buoy during adverse weather is most important. If the ship is snubbed up close, the pull is generally upward, tending to break the buoy loose from its moorings. In addition, the lack of substantial weight of chain permits the transfer of the ship movements to the buoy to be horizontal with the weight of chain providing a cushion for the surges. Scopes as great as

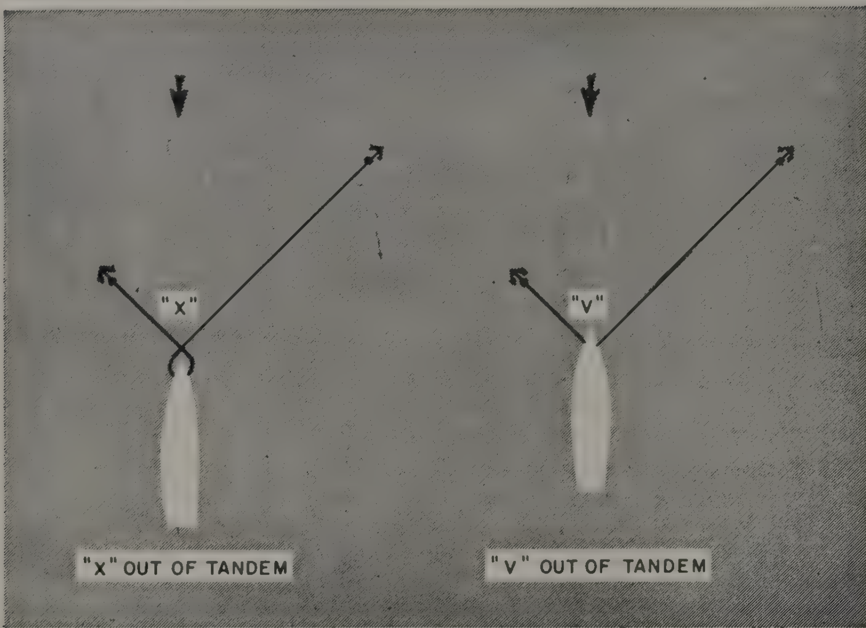


FIG. 8.10 ANCHORS ACTING AS A BRIDLE

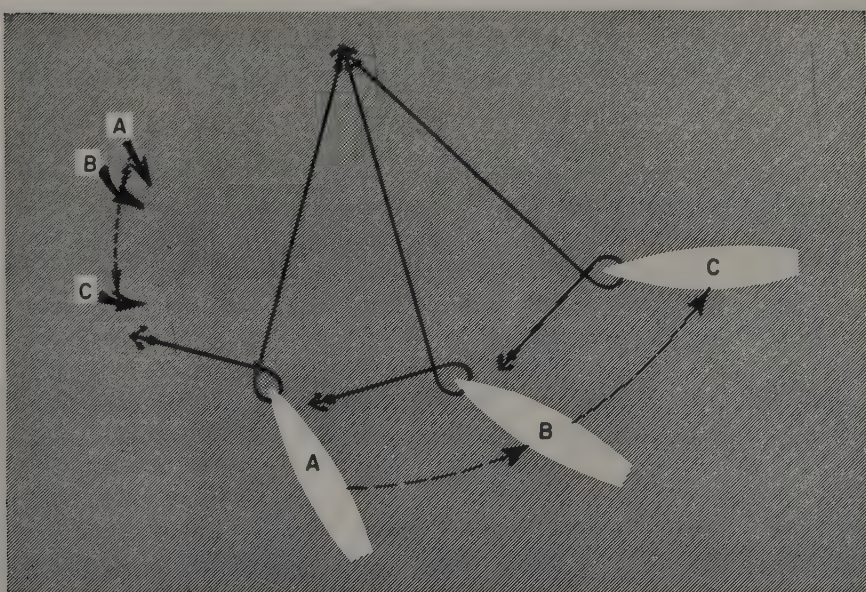


FIG. 8.11 EFFECT DESIRED AS SHORT-SCOPE ANCHOR DRAGS PROPERLY

45 fathoms have been used to good advantage, and where circumstances permit, the chain to the mooring buoy should be veered to produce a catenary such that the chain is never straightened out by the ship's movements. The Hammerlock Moor can also be used at a buoy to control "horsing," but care must be exercised to veer adequate chain before dropping the second anchor to ensure that it is dropped well outside the anchor clump to which the buoy is secured.

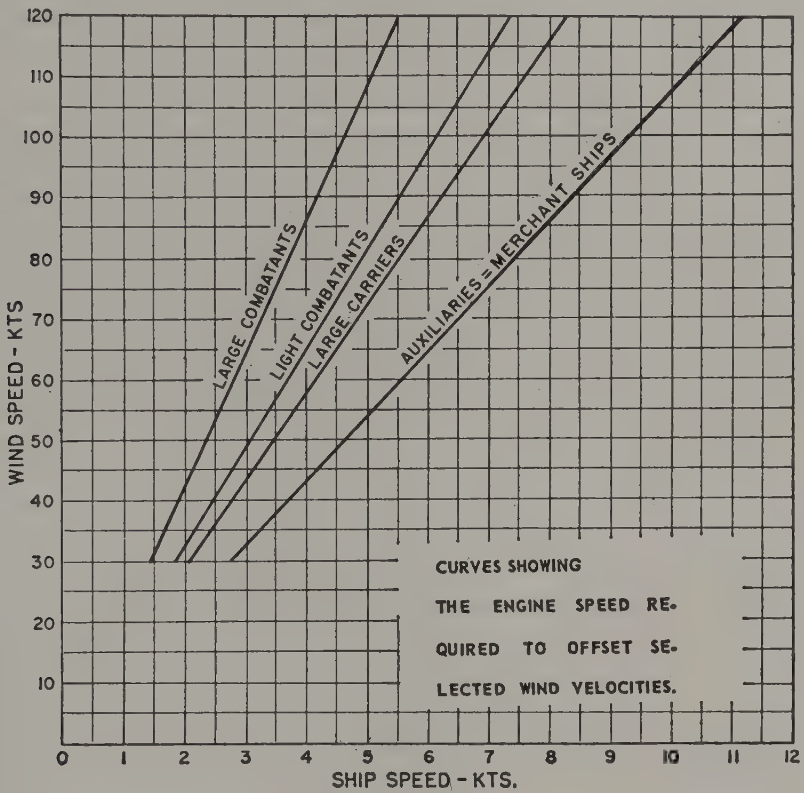


FIG. 8.12

8.24. Wind Velocity—Ship's Speed. The number of knots of engine speed required by a vessel to offset any given headwind velocity should be valuable information to seamen and navigators. This will be particularly true during storms at anchor where such information could assist a master in his efforts to use his engines to prevent dragging anchor. It could also be of value when secured to a buoy. A navigator of a ship under way could use the information to assist in computing the retardation of his ship being caused by a steady headwind. It could also be used by a task force commander to compute the loss of speed by the guide of his formation, and by a master while fueling or transferring stores alongside a station ship, while underway, to compute the difference in loss of speed between his vessel and the station ship.

Four representative types of ships were selected and the curves for them (Fig. 8.12), as developed by the Bureau of Ships, are shown. It is believed that a person having general knowledge of the superstructure and hull design of ships could make an acceptable interpolation from these curves for any vessel.

The curves in Fig. 8.12 were developed using the basic formula:

$$\text{Wind load} = R_w A V^2$$

where R_w is equal to wind friction factor. (R_w is generally taken as 0.004.)

V is equal to wind velocity in knots.

A is equal to projected area above the waterline in square feet.

Three sets of calculations with varying R_w were used. The plotted values illustrated represent the mean of these values.

Since the curves represent the engine speed required to offset completely any given wind speed and hold the ship in equilibrium against the wind without any assistance from the anchors, an engine speed of perhaps 1 to 3 knots less than that selected from the curves should be used by a ship at anchor; otherwise, the ship would be in equilibrium with the force of the wind, and the anchor chains might cease to hold her head into the wind. Also there could be danger of overriding the anchors and fouling the ground tackle.

9

Cargo Handling and Replenishment

This chapter will describe various methods of handling cargo, most of which are common to the Merchant Service as well as the Navy. During time of national emergency, a knowledge of cargo handling on all types of vessels may become necessary.

Merchant Marine advances in speed and ease of handling cargo have been prompted by the demands of economic competition. One significant development is *containerization,* which deals with multiple cargo items in large, already-packed-and-crated (containerized) units.

Navy ships are designed for specialized functions, more so than merchant types; and this has led in recent years to advancing the art. The merchant marine tends to retain the conventional types of rigging until a newer type proves more economically competitive.

9.1. Topping and Spotting Booms. Standard cargo booms are capable of handling at least 5 tons. However, the standard booms on the more recent ships are of at least 10 tons' capacity. Booms must be topped (vertical movement) and spotted (horizontal movement) and then secured in position before cargo can be worked.

To position and secure a boom, a knowledge both of the nomenclature (see Fig. 9.1) and of deck seamanship procedures is required.

1. After determining that all winch controls are set in the OFF position, request "Power on Deck." (Steam winches should be drained before use.)
2. Test the winches.
3. Assign men to winches, guys, whips, topping lift, and gypsy heads.
4. Lay out guys and preventers to proper fittings.
5. Lay out topping lift wire or bull line along the deck. Take five or six turns with topping lift wire, or bull line, around gypsy head in the opposite way from the whip (if the whip goes over the top of the drum, run the topping lift wire underneath the gypsy head). A man should be positioned as back-up man on the topping lift.

Tending the gypsy is the key job in topping or lowering booms. Five or six round turns about the gypsy are recommended when working with wire rope. Fewer turns are likely to slip, and more turns are likely to form slack in the wire. These slack turns may fall over the edge of the gypsy and cause the boom to drop. It is a good practice to assign one or two men to back up the man on

the gypsy. These men can keep the wire from kinking, keep it clear of the winch, and aid the man on the gypsy in case of trouble.

6. Assign one man to overhaul the whip as the boom is topped.
7. Raise boom to the desired height.
8. Secure topping lift as follows:

   a. *Single Topping Lift.* Shackle bull chain to pad eye as shown at (31) in Fig. 9.1, and slack off on the bull line until bull chain takes the strain.

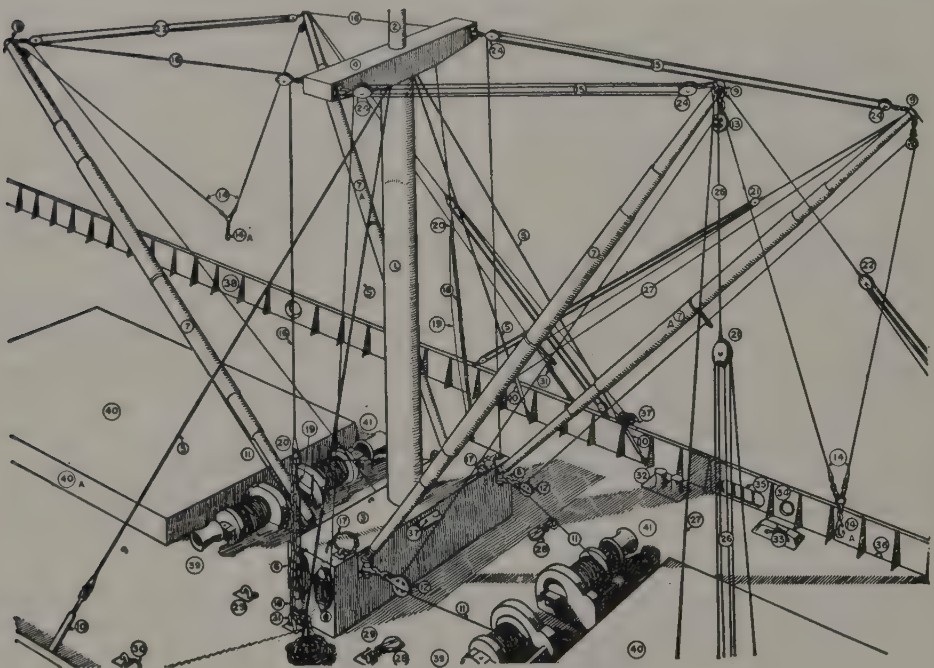


FIG. 9.1 CARGO HANDLING GEAR

NOMENCLATURE FOR FIGURE 9.1

1. Mast
2. Topmast
3. Mast table
4. Crosstree
5. Shroud
6. Topping lift cleat
7. Hatch boom
7A. Yard boom
8. Gooseneck
9. Linkband
10. Turnbuckle
11. Cargo whip
12. Heel block
13. Head block
14. Cargo whips
14A. Cargo hook
15. Topping lift (multiple)
16. Topping lift (single)
17. Stopper chain
18. Bull chain
19. Bull line
20. Bale
21. Outboard guy
22. Inboard guy
23. Midship guy
24. Topping lift block
25. Guy pendant
26. Guy tackle
27. Preventer
28. Snatch block
29. Pad eye
30. Pad eye and ring bolt
31. Shackle
32. Bitts
33. Open chock
34. Closed chock
35. Freeing port
36. Scupper
37. Cleat
38. Bulwark
39. Hatch winch
40. Cargo hatch
40A. Hatch coaming
41. Yard winch

Throw bull line off the gypsy head and secure it to the topping lift cleat with a minimum of three round turns and three figure eights.

b. *Multiple Topping Lift.* Apply stopper chain to topping lift wire, using stopper (rolling) hitch and two half hitches. Take turns around the wire with the remainder of the chain and hold it. Surge the topping lift wire until the stopper takes the strain and belay it as described for the single topping lift. Remove the stopper.

9. Spot booms in a working position by hauling on the guys. The yard boom is positioned over the pier, clear of the ship's side. The hatch boom is spotted slightly past the centerline over the hatch.

10. Set up on outboard guys and preventers. Guys should be slightly more taut than preventers. Set the inboard or midships guys as taut as possible by hand. Shackle the cargo whips to the cargo hook and pick up a load. Raise the load until the angle formed by the whips is about 120 degrees. Now equalize the outboard guys and preventers by easing off the guy tackles. As outboard guys and preventers are being equalized, take in all slack in the inboard or midship guys. It is a good practice, when originally spotting the booms, to swing them slightly wider than desired. When guys and preventers are equalized, the booms will move inboard into position.

There are several methods of raising and lowering booms. The standard practice is to apply the topping lift wire directly to the drum of the winch. This is the safest method, but the time required may be prohibitive.

Cargo ships being constructed, and some already in service, have special topping lift winches installed on the masts and king posts. These winches offer greater speed in raising and lowering booms. To top booms you merely run the winch until the boom is at the desired angle.

Another method of topping and lowering single topping lift booms is by means of the cargo whip which is led from the head block through a fairlead block at the base of the mast, then shackled to one of the top links of the bull chain. By taking in on the whip, the boom is raised; by slacking off, the boom is lowered. This is the least desirable method and should not be considered unless the other methods cannot be used.

9.2. Yard-and-Stay Method. In the yard-and-stay method of cargo handling, two booms are used. One of these booms is called the hatch boom and it plumbs the hatch. The other is called the yard boom and it is rigged out over the side so that it plumbs the dock or pier. (See Fig. 9.2.)

The cargo whips coming from the hatch and yard winches are rove through their respective heel and head blocks and are shackled to the same cargo hook.

If the whip has a thimble spliced in the end in the usual manner, it may be impossible to reeve the whip through the block, making it necessary to remove the whip from the winch drum so that the winch end may be rove through.

Another method is often used by Navy ships on which cargo operations are not the rule and where cargo-working gear is struck below until needed. A

large eye is formed by turning back the end of the whip upon itself and securing, with wire rope clips, the eye thus formed. It is thus an easy matter to remove the clips, reeve the whip through the blocks and replace the thimbles.

The winch controls are usually located in such a position that one man can operate both winches and have an unrestricted view of the hold.

A load is moved from hold to pier in the following manner: The yard whip is kept slack as the hatch whip hoists the load from the hold and clear of the

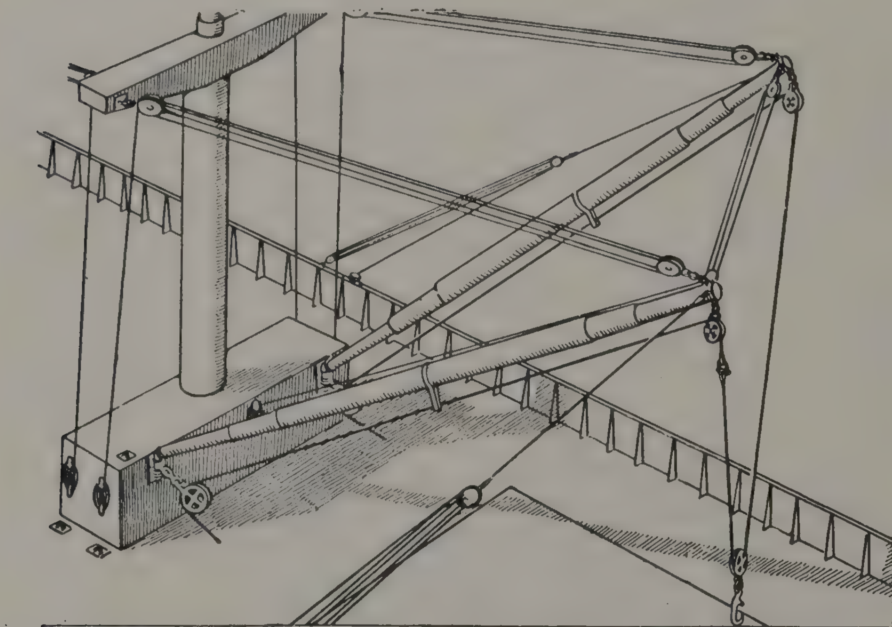


FIG. 9.2 YARD-AND-STAY WITH MIDSHIP GUY

coaming. Then, by heaving around on the yard whip and paying out on the hatch whip, the load is burtoned across the deck and over the side. When the load is plumbed under the yard boom, the hatch whip is slacked off and the yard whip lowers the load to the pier.

Nearly all methods of rigging yard-and-stay cargo-handling gear for heavy lifts require that the cargo whip be doubled-up and a block used. Doubling-up the whip accomplishes two things: it doubles the load that may be lifted by the whip, and it reduces the load on the winch by half.

Most yard-and-stay rigs use ⅝-inch wire; therefore a block with at least a 12-inch sheave must be used for a runner block. Larger whips, of course, will require larger runner blocks (¾-inch wire requires a 14-inch block).

The end of the whip may be secured in several ways. The best method is to shackle the eye of the whip to the upper end of the boom. (See Fig. 9.3.) This tends to keep the bight of the whip from turning on itself and becoming

wrapped up. It has the advantage of steadying the swing of the load in a fore-and-aft direction.

9.3. Yard-and-Stay Double Purchase. The chief advantage of the yard-and-stay double purchase is that lifts as heavy as the safe working load of the cargo booms can be handled at nearly the same rate as ordinary 1- or 1½-ton drafts. Light filler cargo encountered during the operation can be handled with scarcely any loss of time.

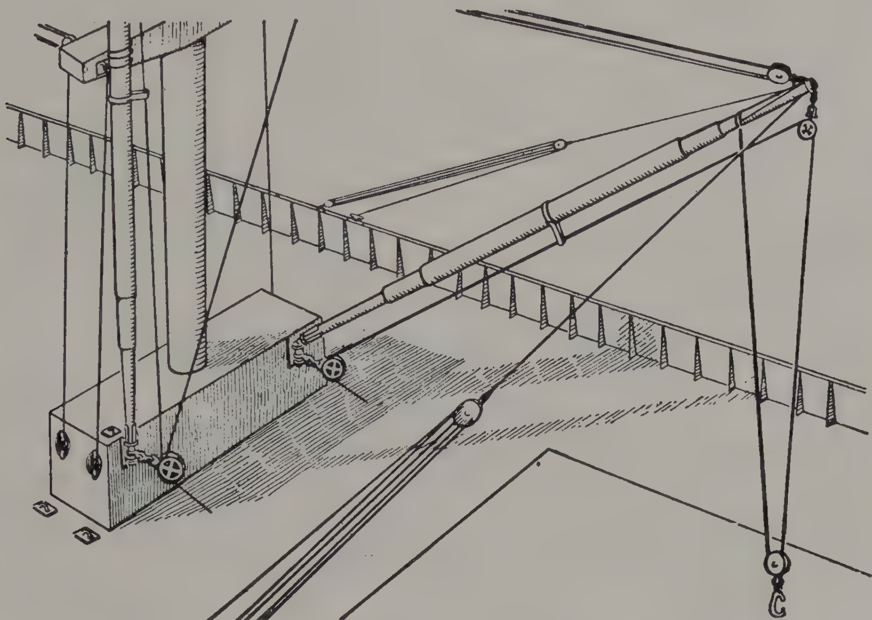


FIG. 9.3 SINGLE SWINGING BOOM WITH DOUBLE PURCHASE

The only difference between this rig and the ordinary yard-and-stay is that both cargo whips are doubled up and the runner blocks shackled to the cargo hook.

9.4. Single Swinging Boom with Double Purchase. The single swinging boom with double purchase is considered one of the best methods of rigging for handling loads beyond the capacity of a *single whip* up to the capacity of a single boom. It is quickly and easily rigged and has the added advantage of flexibility. Load may be placed at any point in the square of the hatch or on the deck.

The yard boom will be the one to be rigged, so the hatch boom is topped up and secured out of the way. (See Fig. 9.3.)

The procedure for rigging the boom is as follows:

1. Strip the hatch whip from its drum and replace it by the yard boom's topping lift wire. Make sure the topping lift wire has a fairlead. This can only be done with a boom which has a multiple topping lift.

2. See that the yard whip is long enough to permit doubling-up (250 to 300 feet).

3. Double-up whip.

4. Remove preventers from yard boom, and lead guys to proper fittings.

5. Top up the boom and swing into position by hauling on guy tackles. The hauling part of the guys may be fairled to winches at adjacent hatches, or men may be assigned to haul on the guys when swinging a load.

9.5. Two Swinging Booms. A load greater than the capacity of a single boom may be handled by using two booms working together as a single swing-

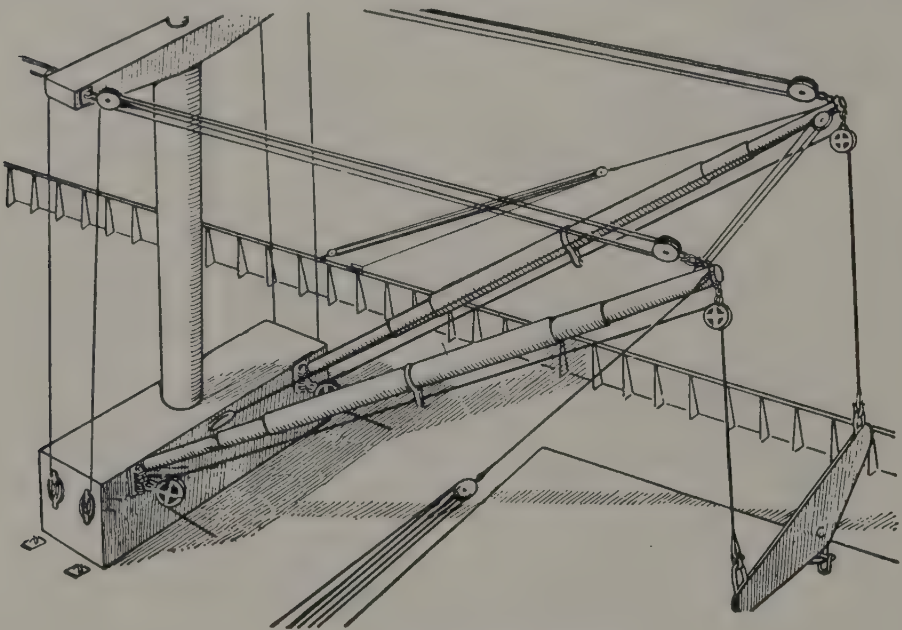


FIG. 9.4 TWO SWINGING BOOMS

ing boom. In this case, the whip of the two booms should be fastened to opposite ends of a lifting bar or strong back, as illustrated in Fig. 9.4. The lifting bar serves to equalize any difference in winch operation.

To move a load from the hold to the pier, it first is hoisted clear of the coaming. Then, by using the guys, both booms are swung in unison until the load is over the pier. The load is then lowered to the pier. Swinging the load is a difficult operation, and it may be necessary to set the load on deck to change the position of the booms. Because this rig is cumbersome and difficult to handle, it should be used with great caution.

9.6. Block-in-Bight Method of Rigging a Double-Ganged Hatch. Many ships have double-ganged hatches, i.e., they are equipped with two pairs of ordinary cargo booms. Handling heavy lifts at a hatch in this manner is facilitated by rigging all four booms as illustrated in Fig. 9.5.

The rigging procedure is as follows:

1. Reeve the forward hatch whip through a runner block, and shackle the eye to the eye of the after hatch whip. Reeve the forward yard whip through a runner block, and shackle it to the after yard whip.

2. Run the shackles joining the two sets of whips to within a few feet of the head blocks of the after booms.

3. Shackle the two runners blocks to the cargo hook.

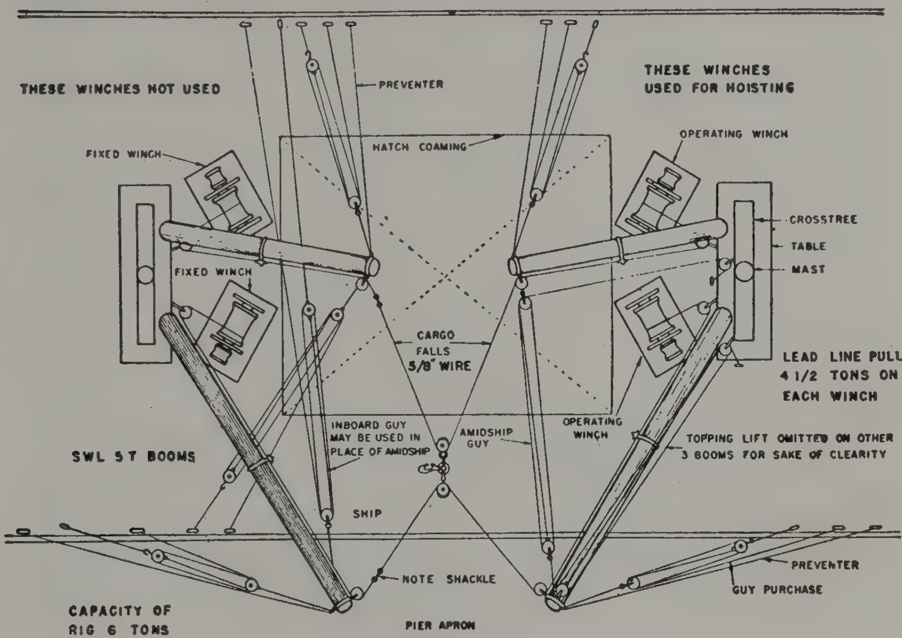


FIG. 9.5 RIGGING A DOUBLE-GANGED HATCH

4. Heavy lifts slightly less than the sum of the safe working load of two parts of the cargo whips may now be loaded or discharged by the usual yard-and-stay method.

5. This rig has the advantage of being quickly rigged without the necessity of lowering the booms, and only two winches are required for its operation. In addition, the gear may be readily singled up for ordinary light loads.

9.7. Unrigging and Securing for Sea.

1. Assign men to winches, guys, whip, topping lift, and gypsies.
2. Cast off preventers.
3. Remove topping lift wire from cleat as described below.

   a. *Single Topping Lift.* Remove bull line from cleat, place it in a snatch block, fairleading it to the gypsy. Take five or six turns around the gypsy in the same direction as the whip (over the top), and top up

boom until the bull chain is slack. Unshackle the bull chain and lower boom to its cradle.

b. *Multiple Topping Lift.* Pass the stopper chain on the topping lift wire and remove the figure eights from the cleat. Surge the topping lift wire until the stopper takes the strain, then shift the wire to the gypsy. Heave around on the wire until the stopper is slack. Remove the stopper and lower the boom. If the cleat is large enough and conditions warrant, the boom may be lowered to the cradle by surging the wire around the cleat instead of transferring it to the gypsy. However, only experienced men should attempt this.

Regardless of the type of topping lift, men on the guy tackles must keep all the slack out of the guys to prevent the boom from swinging while it is being lowered and cradled.

While the booms are being lowered, cargo whips should be tended to prevent turns from piling up on the drum of the winch.

When both booms are cradled, all gear should be secured. Whips are rewound smoothly on the drum of the winch and the cargo hook is secured to a ring or cleat with a slight strain. Guys are secured to the heel block, or fittings on the mast table, then set taut. The hauling parts of the guys are coiled over the guy tackles and tied off. Topping lift wires or bull lines are secured to cleats with the remainder of the wire coiled and hung on a cleat. Bull chains are shackled to pad eyes on deck. If the ship is being made ready for sea, all running rigging and cargo-handling gear is secured.

9.8. Safety Precautions. Because topping and lowering booms are dangerous operations, safety must be emphasized. Men must be cautioned to stay from under booms while raising or lowering operations are in progress. The deck should be kept as clear of loose gear and lines as possible. A clean and orderly deck is safest.

The stopper chain of the topping lift must be properly secured; otherwise serious accidents may result. A rolling hitch and two half-hitches with several round turns are recommended. They are applied quickly, hold securely, and may be removed easily.

Topping lift wire should be secured about the topping lift cleats with a minimum of three round turns followed by three figure eights. To prevent the last few turns from slipping off the cleat, mouse the last two figure eights. Never half-hitch a topping lift wire around a cleat. It may tighten and become virtually impossible to remove. In lowering a boom by surging, the mousing and the three figure eights are removed, after which the three or four turns are gradually surged. This should only be done by an experienced man.

When shackling a bull chain to a pad eye, the shackle should be inserted beneath the first slack link in the chain. Otherwise, this loose link and the shackle may crowd the bottom of the chain, thus causing dangerous distortion and strain.

9.9. Jumbo Booms. Tanks, landing craft, harbor boats, crash boats, locomotives, and other extremely heavy cargo required by forces present difficult problems in stevedoring operations. Loading a heavy lift is usually a simple matter at ports in this country; however, the problem does not end at these ports. At overseas bases these heavy lifts must be offloaded, and shoreside equipment or floating cranes are not always available. Where it is known that

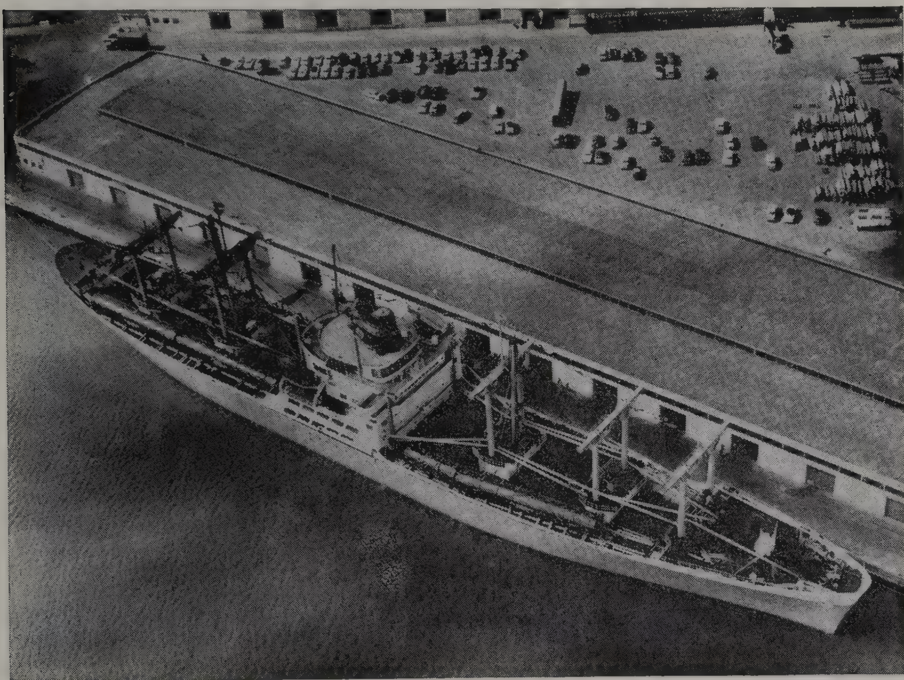


FIG. 9.6 BOOM PLACEMENT ON MARINER TYPE SHIP. *Official Photograph, Maritime Administration, United States Department of Commerce*

heavy lift capability is not available or when doubt exists as to its true capacity, the ship's own gear should be used for the job. Careful planning must be done to assure that heavy lifts, loaded with stateside shore cranes, can be discharged by the ship at an overseas port.

Most modern ships are fitted with jumbo booms of 30- or 50-ton capacity, normally located at one of the largest hatches of the vessel. Some Navy ships are equipped with 60-ton booms to handle the largest size LCM's. Installations on "Mariner" type cargo ships include a 50-ton boom at the No. 3 hatch and a 50-ton boom at the No. 6 hatch. (See Fig. 9.6.) Cargo ships being built in the "trade-in-build" program under subsidies by the government are now being equipped with cargo booms capable of up to 75 tons. Many are being equipped with "stulcken" booms, which have the ability to serve two adjacent hatches with a 75-ton capability. Additionally, most ships now being built are fitted

with quick-acting metal hatch covers in place of the older conventional hatch beams and boards.

Many ships used in task-force operations are provided with heavy lift gear at practically all hatches for the expeditious discharge of such heavy equipment as landing craft, tanks, and bulldozers. Practically all cargo-handling personnel operating in the field will have occasion to work heavy lift rigs, and for this reason must understand rigging and operating procedures of jumbo booms. (See Fig. 9.7.)

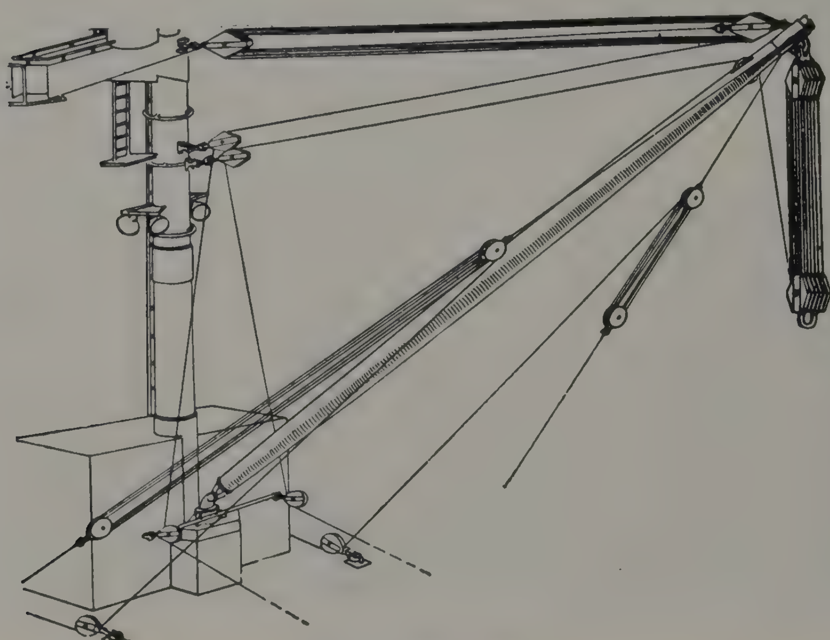


FIG. 9.7 JUMBO BOOM

Most jumbo booms are carried in an upright position, collared to the mast or king post and fully rigged, with topping lift, load purchase, and guy tackles already secured.

This first step in rigging a jumbo boom is to lead all purchases to power. Four sources of power are required. The load purchase and the topping lift wire are led through heel blocks to the winches at the hatch to be worked. The guy tackles are led out to proper fittings, and the hauling parts of the guys are led to adjacent sources of power. The winches at adjacent hatches may be utilized, depending on the location of the boom.

To free the boom for use, it is necessary to send men aloft to release the collar that secures the boom to the mast.

Before making a hoist with a jumbo boom, all gear should be thoroughly checked to make sure blocks are running free and that none of the lines are

chafing. Turns of wire on the drums of winches should lay tight and evenly around the drum. Guy tackles should be free of twists, and hauling parts of guys should fairlead to sources of power. Hasps and hooks of snatch blocks should be moused securely with seizing wire. Stays, shrouds, and preventers must be checked and tightened if necessary. This is extremely important, for it is possible to bring down a mast in attempting to handle a heavy lift.

Before a jumbo boom is operated, swing the ordinary cargo booms at the hatch clear of the working area. Generally, it is sufficient to swing these booms outboard against the shrouds and secure them with the guys. In working deck cargo, however, it may be necessary to top the booms very high in order to clear the deck space.

The head of the boom must be plumbed directly over the load and the slings carefully slung and shackled to the lower purchase block. Then the load is hoisted a few inches off the deck and all gear carefully checked for any indication of undue strain. Hoist the load carefully until it is clear of the hatch coaming. By heaving around on the guy tackles, the boom is now swung over the ship's side, and the load may then be set on pier.

One of the greatest difficulties in working a jumbo or heavy lift boom is handling the guys. Every change in position of the boom must be accompanied by a change in adjustment of the guys. When a boom is topped, the guys must be slacked off; when it is lowered, the guys must be taken in. To swing a boom, one guy must be heaved in on and the other slacked off, and this requires coordination between the men handling the guys.

When a boom is swung outboard or inboard, one guy may be considered as a "hauling" guy; the other, as the "following" guy. The latter is generally the troublemaker. Green hands often fail to ease off on this guy smartly enough and it parts with disastrous results. It is good practice to allow a small amount of slack in a following guy, but never enough to permit the boom to slap about.

A heavy lift suspended outboard from the head of a jumbo boom may cause a ship to develop a considerable list. This places a great deal of added strain on the guys. The boom has a natural tendency to swing outboard in the direction of the list, and if this is not properly controlled, a guy tackle may easily carry away.

9.10. Precautions. Rigging and operation of cargo booms used for heavy lifts require skill, care, and common sense. There are many precautions to be observed, and to neglect any one is to invite trouble.

1. Don't overload. Make certain that the rig will make the lift safely; rig carefully and check each piece of gear as it is rigged. Check stays and shrouds.

2. Plumb the load directly under the boom head. Sling carefully and use dunnage or other suitable chafing gear at points where there may be chafing.

3. Check every part of the rig before picking up the load. Hoist the load a few inches off the deck, and check the rig for indications of undue strain.

4. Hoist, swing, and lower the load slowly and smoothly. Jerking causes terrific strain in the rig and can easily part something. Hoist loads only high enough to clear the coaming and bulwark. A particularly heavy load raised too high will affect the stability of the ship and may cause considerable list. Listing increases the strain on the guys and preventers and therefore the danger of parting. If something does part when a load is raised high, the effect will be worse than if the load were lower.

5. WATCH while a load is being moved, and keep every part of the rig under constant observation. LISTEN for any change in sound. A wire or fiber rope will normally hum under strain, but when it starts to squeak or squeal, LOOK OUT. A faulty block may give warning by squeaking or groaning.

6. Keep unnecessary personnel out of the area; those concerned with the operation must keep alert.

7. LOOK ALIVE AND STAY ALIVE.

All safety precautions should be strictly observed by all hands at all times. The following list contains common sense precautions that all cargo handlers must observe.

1. Wear safe clothing and shoes. Do not wear trousers that are too long, and do not wear rings while at work.
2. Use the accommodation ladder or brow for boarding and leaving the ship.
3. Climb ladders in the hold only when hoist is not in motion.
4. Use the walkway on ship's side away from the side on which the hoist is operating.
5. Secure hatch rollers properly.
6. Lower blocks, crowbars, chain slings, bridles, etc., into the hold by cargo falls or other lines.
7. Pile hatch covers in an orderly manner.
8. Lay strongbacks flat so they will not tip over on personnel or be dragged into hatches or overboard by slingloads.
9. Stand in the clear when strongbacks and hatch covers are being handled on the deck above.
10. Stand in the clear away from suspended loads.
11. When steadying loads, do not stand between load and any fixed object. Always face the load and keep feet and hands in the clear.
12. Stand clear of slings being pulled from under loads by cargo falls.
13. When using a dragline to move cargo, stand out of the bight and clear of the throw of the block and hook.
14. Be especially attentive when handling objects with sharp or rough edges.
15. Learn to lift properly to prevent strain.
16. Always use a light when entering dark places.
17. Never walk backwards while working with or around cargo on board ship.
18. Step down from elevations—never jump down.
19. Bend over projecting nails in dunnage to prevent puncture wounds.

20. Report to your supervisor any defect in tools, materials, appliances, and gear.

21. When short pieces of dunnage are required, use only the proper cutting tools.

22. Report all injuries (even scratches, cuts, and splinters) to your supervisor and get immediate first-aid or medical attention.

23. Know the location of fire-alarm boxes and fire-fighting equipment.

24. Do not engage in horseplay, practical jokes, or arguments.

Replenishment at Sea

Replenishment at sea is the term applied to the transfer of fuel, munitions, supplies, and men from one vessel to another while ships are under way. The first significant replenishment operation at sea in the U.S. Navy was in 1899, when the collier *U.S.S. Marcellus,* while being towed, transferred coal to a warship, the *U.S.S. Massachusetts.* Since that time, many methods have been tried and abandoned. Those described in this chapter have been adopted as the most feasible and are currently used in the fleet.

The cargo of a replenishment ship is intended for delivery to a base, replenishment group, or to the fleet at sea. It is the fleet-issue-loaded vessel with its varied cargo, stowed for quick and easy handling at sea, that will be discussed in this chapter.

9.11. General Discussion of Replenishment. The cargo of the replenishment ship is determined by one of the following considerations: (a) Requisitions prior to loading, (b) anticipation of fleet requirements, or (c) need for issuing provisions and stores in standard units. A package or kit which contains a specified grouping of items in fixed quantities, usually pallet loaded, is considered to be a standard unit.

There are four general principles for the loading of ships replenishing the fleet at sea to ensure maximum efficiency in unloading.

1. Lots of homogeneous cargo should be stowed, if possible, in several holds, so that they may be off-loaded at as many transfer stations as possible.

2. Provision must be made for adequate passageways and working areas in and around the cargo to permit quick segregation of lots, checking, and separate handling of heterogeneous types of supplies. Loading must be planned so that the remaining cargo can be readily reshored at the completion of replenishment to reduce the danger to personnel from shifting cargo.

3. Bulky and heavy items must be placed near loading areas and in holds that can accommodate their transfer most readily. The hatch opening, the height of the hold, and the fact that certain types of receiving ships can receive bulky items only at certain stations must all be considered.

4. Replenishment must be accomplished at the highest possible tonnage rate per hour and in the shortest practicable time consistent with safety.

Normally the receiving ship maneuvers to take station on the delivering

ship and adjust course and speed as necessary to maintain station during the operation. However, when large aircraft carriers are to be replenished, the replenishment ship may complete the final phase of the approach.

The delivering ship may use line-throwing guns with all types of receiving ships except carriers. The danger of firing gun lines into the hanger deck areas where supplies are being received makes it necessary for carriers to fire lines to the delivering ships.

Except for gear actually rigged on the receiving ship, such as fairlead blocks, riding lines, etc., the delivering ship furnishes all equipment during replenishment.

The zero end of the distance line is secured at or near the rail of the delivering ship, and the other end is tended on the receiving ship.

Each station on both ships has a telephone talker, and a signalman who is familiar with prescribed signals.

There are several methods which can be used to transfer cargo at sea. The tabulation below provides the load capacities of these methods under normal operating conditions. These figures must be reduced when transferring in rough or heavy seas.

Method	*Maximum Capacity per Load (pounds)*
Burton	3500
Housefall	2500
Double housefall	2500
Modified housefall	2500
Wire highline	800
Manila highline	600

9.12. Burton Method. The procedure for rigging a burton station on the delivering ship, using the port boom for transfer (burtoning), and using the starboard boom as the hatch boom (hoisting cargo out of the hold) (Fig. 9.8) is as follows:

1. Secure the inboard end of the *bridle messenger* to the bridle and fake it down on deck. Lead the eye-spliced end outboard in the vicinity of the transfer stations.

2. Fake down the *burton whip messenger* on deck and attach its snap hook to the bridle.

3. Fake down the telephone and distance lines and attach to the bridle.

4. Secure the thimbled eye of the burton whip, which is a 6 x 37 high-grade plow steel wire rope, $\frac{5}{8}$ or $\frac{3}{4}$ inch in diameter and 350 to 600 feet long, to the triple swivel and hook of the engaged boom. Reeve the bitter end of this wire through the head and heel blocks. Secure the bitter end of the whip to the winch drum and spool the whip onto the drum.

5. Secure a *preventer* of at least 1-inch high-grade plow steel wire to the inboard side of the boom head and secure the pins of all shackles with seizing wire. Top up the boom so that the cargo whip plumbs the desired transfer point on the port side of the main deck. Set up guys and belay. Lead the pre-

venter to the starboard side of the ship as close to a 90 degree angle from the boom as possible, or a provided fixed position. Apply strain and belay the preventer.

9.13. Burtoning Procedure. When the receiving ship completes her approach on the delivering ship, a heaving line (or line-throwing gun line) is sent over by the delivering ship. This line is attached to the bridle messenger, which is then hauled aboard the receiving ship. Attached to the messenger is the bridle and the lines attached to it. As soon as the bridle is received, the

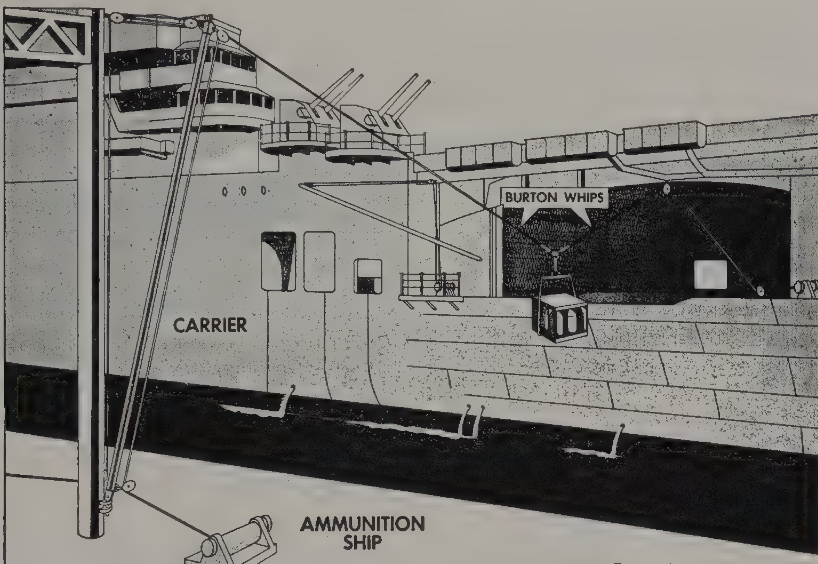


FIG. 9.8 BURTON RIG

telephone and distance lines are secured and walked clear of the receiving station. The receiving ship takes the burton whip messenger from the bridle and then secures her burton wire to the messenger. The burton wire is hauled back to the delivering ship and secured to the triple swivel hook. The ships are then ready to transfer cargo.

Burtoning stations on the receiving ship are rigged in accordance with plans which designate the burton point for each type and class of ship. The burton whip block is secured to the burton fitting. The bitter end of the whip is rove through the whip block, and then led to the designated winch drum or gypsy head. The thimbled eye of the burton whip should be on deck ready for passing when the burton whip messenger from the delivering ship with attached snap hook is received on board.

The beckets, or sling, of the load are placed on the cargo hook of the burton whip. The delivering ship then hoists the load clear of the deck and rail. The receiving ship takes in on her burton whip as the delivering ship slacks away

and the load is worked across. When the load is suspended over the receiving ship's deck, her whip is slacked and the cargo lowered to the deck.

Successful burtoning necessitates teamwork between the winchmen of both ships. Steady tension should be maintained on each whip regardless of movement due to rolling and yawing.

Stress in rigging may be reduced to a minimum by keeping the load as low as possible (consistent with sea conditions) and hoisting it just high enough to clear the rails of the two ships. As the load crosses between ships, it should be lowered to trace a catenary yet be maintained at a sufficient height to prevent immersion.

On completion of the replenishment operation, the burton whip is returned by means of the burton whip messenger to the delivering ship. The messenger, along with the telephone and distance line, is attached to the bridle and payed out with the bridle messenger. All messengers are returned in the same manner as received, only in reverse order. Thus, the time required for rerigging on the delivering ship will be reduced, and preparations for transferring cargo to the next receiving ship will be expedited.

9.14. Housefall Method. Rigging for housefall transfers can be done in several ways, making use of one or two booms. The housefall boom and whip can be plumbed over the center of the hold, thus serving the twofold purpose of lifting cargo to the deck and then transferring it to the receiving ship. This method, however, reduces the rate of transfer because of the longer distance the hook travels. Rigging procedure described requires two booms, as shown in Fig. 9.9.

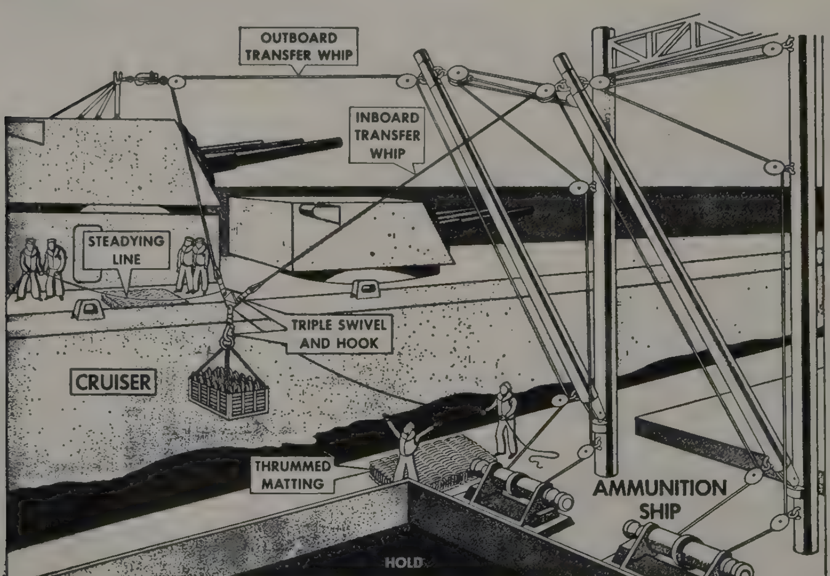


FIG. 9.9 HOUSEFALL RIG

Rigging the normal housefall as described below requires the use of two booms of the delivering ship, one boom located at the active hold and one boom at the hold forward of the active hold:

1. Secure the thimbled eye of the cargo whip to the triple swivel and hook, reeve the bitter end of this wire through the head and heel blocks of the boom at No. 2 hold and spool it onto the winch drum. The position of the boom, the guys, and the preventer are the same as for burtoning.

2. Secure temporarily the housefall block (a runner block of 12 or 14 inches) to the bulwark with a short piece of 2-inch manila line outboard, opposite the center of the hold.

3. Secure the thimbled eye of the transfer whip to the triple swivel and hook. Reeve the bitter end of the whip through the housefall block (outboard of all projections and rigging), walk it forward, reeve it through the head and heel blocks of the boom at No. 1 hold, and then spool it onto the winch drum.

4. Secure galvanized preventer wire (at least 1-inch high-grade plow steel) to the inboard side of each boom head. Top up the booms so that its whip clears all standing rigging or projections when making transfers to the receiving ship.

5. The remaining steps in rigging the delivery ship are the same as for burtoning.

9.15. Housefall Procedures. The receiving ship secures a gin block to the suspension point (same as for burton). A wire pendant (¾ inch 6 x 37 high-grade plow steel) with a thimbled eye, is run through this block. The thimbled eye remains on deck for attachment to the pelican hook of the housefall block.

When received, the hook is secured to the thimble of the housefall block eye. A strain is applied to the wire pendant until the housefall block is two-blocked and the hauling part is then secured.

The housefall block messenger is detached from the bridle and used to haul the housefall block over as the delivering ship pays out on the housefall transfer whip. The block is then secured to the wire pendant and made ready for cargo transfer.

On the delivering ship the load is hoisted clear of the rail with the housefall cargo whip. The strain is taken on the housefall transfer whip, and the load is worked over to the receiving ship.

On completion of the transfer operation, the lines are passed back to the delivering ship in the usual manner. This type of rig proves advantageous when the receiving ship cannot keep good fore-and-aft position.

When loads must be kept higher above the water than is normally possible in housefalling, the housefall rig can be modified by the addition of a trolley block on the transfer whip.

9.16. Double Housefall. The double housefall speeds transfer of cargo to ships that do not have sufficient suspension points to handle more than one rig. However, double housefalling is somewhat slower than housefalling to two separate receiving stations.

In a double housefall operation the delivering ship uses two adjacent housefall rigs. Both housefall blocks are passed over the receiving ship simultaneously. In operation, one housefall rig alternately passes a loaded net to the receiving ship while the other returns an empty net to the delivering ship. The separation of the two housefall rigs on the delivering ship must be a minimum of 25 feet to prevent the outboard whips from fouling.

9.17. Wire Highline. The wire highline is usually used in transfers to destroyers and other small units.

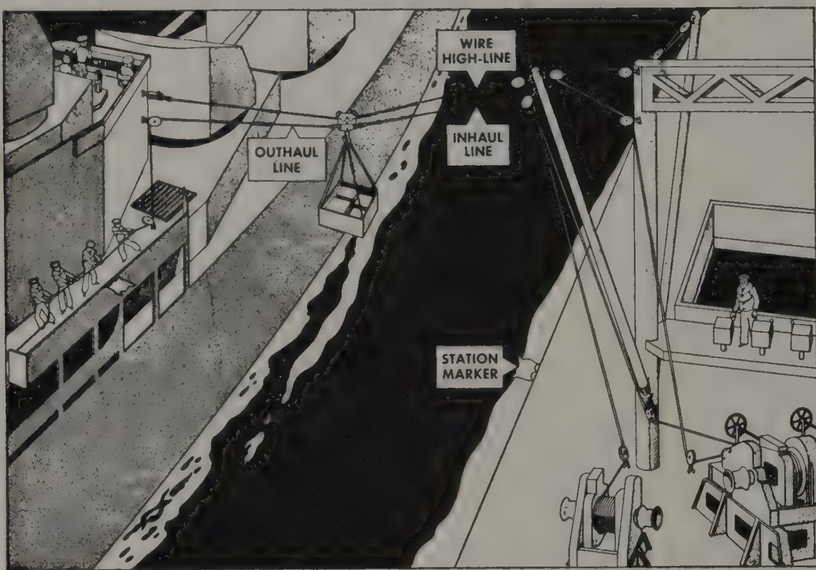


FIG. 9.10 WIRE HIGHLINE RIG

To use the wire highline, the receiving ship must have a high attachment point. This is usually a pad eye welded to the ship's house structure. There is also an additional pad eye of 1-inch diameter located below about 12 to 18 inches from the first pad eye. The block used to fairlead the inhaul line is attached to this second pad eye. Sufficient deck space must be provided in the vicinity of the pad eyes to handle cargo being received.

The highline passes from a winch on the delivering ship through a block on a boom head and then across to a pad eye on the receiving ship (Fig. 9.10). A trolley rides the highline and is moved toward the receiving ship by an inhaul line (manually handled) and is brought back to the delivering ship by an outhaul line (winch operated).

A boom is normally used to provide a satisfactory lead for the wire highline. However, any other point of suspension on the ship's structure will serve if it is sufficiently high and strong. The highline is normally 350 feet of $\frac{5}{8}$- or $\frac{3}{4}$-inch wire (high-grade plow steel) with a thimbled eye on its outboard end. The following description is of a boom rigged highline:

1. Reeve the inboard end of the wire through a trolley block, through the head and heel blocks of the boom, and then spool it onto a winch drum.
2. Attach a pelican hook to the thimbled eye with a ⅞-inch shackle.
3. Shackle the manila outhaul line (2½ inch) to the inboard end of the trolley block and then run it through an 8-inch wooden block and a swivel attached to a becket on the underside of the head block. (See Fig. 9.10.) The outhaul line is finally taken through a fairlead to the gypsy head of a winch.
4. Equip the manila inhaul line (2½ inch) with a snap hook attached to the bridle. Fake down the center section of the line on deck clear for running and shackle the standing end to the outboard side of the trolley block.

Little preparation is required on board the receiving ship for the highline method. Below the highline pad eye, an 8-inch snatch block is secured to take the manila inhaul line. Additional snatch blocks are rigged to fairlead the inhaul line clear of the landing area. The Drouge Method is a variation of the wire highline and is used more extensively than the straight wire highline. Its advantages are speed of delivery and decrease in manpower required to handle lines.

9.18. Highline Procedure. When the inhaul line comes on board the receiving ship, it is detached from the bridle and led into the blocks provided for it. The pelican hook is secured to the highline pad eye, establishing the highline connection.

The load is now hooked to the trolley block and a strain is taken on the highline, thus lifting the load clear of the deck and rail. The load is hauled across to the receiving ship by slackening the outhaul line and taking up the inhaul line. When the load is suspended over the landing area, the delivering ship slacks off on both the highline and outhaul line, setting the load on the receiving ship's deck.

It is important always to keep a good catenary in the highline to avoid unnecessary strain when a load is suspended.

9.19. Manila Highline. The manila highline can be used in transferring provisions, ammunitions, personnel, and light freight. Preparation for rigging is essentially the same as for a wire highline, and a 12-inch snatch block attached to a pad eye at the delivering station is sufficient. It is kept taut during transfers either by manpower or by a capstan. The entire rig is relatively easy to set up and is the safest method now available for transferring personnel. Considering the manpower involved, however, helicopter transfer is always preferable when practicable.

To transfer individuals singly or in pairs, the only safe rig is the manila highline: all lines can be tended by hand. Heaving in lines by hand, with a sufficient number of men standing by for emergency, is the best method to ensure against the highline parting from sudden strains caused by rolling ships.

The burton method is a means of rapidly transferring 4 or 5 men in a skip box. It is used only when the situation demands quick transfer of a relatively

large number of personnel and time does not permit individual transfer by the standard manila highline method.

9.20. VEREP. VEREP, or vertical replenishment, is the use of helicopters in replenishment. It has found great acceptance in the fleet today. Its limitations now are mainly the number of helicopters available, and this number is increasing daily. VEREP will soon be used more than any other method.

9.21. General Safety Precautions for Transfer and Refueling

1. Personnel assigned to transfer stations must be adequately trained in all phases of safety procedures and precautions. They should wear helmet liners.
2. Because transfer stations on receiving and delivering ships are in exposed locations, personnel working close to ship's sides where solid bulwarks are not installed must wear kapok-type life jackets. If it is necessary to use inflatable-type life jackets, they must be inflated.
3. During heavy weather, personnel working on weather decks should wear life jackets.
4. Personnel must be cautioned to keep clear of suspended loads whenever possible.
5. Ample provision must be made to prevent the shifting of cargo, with its risk to both personnel and material.
6. Wire highline may not be used to transfer personnel. When manila highlines are used to transfer personnel, a capstan may not be employed to tend the line.
7. In handling ammunition, it must be remembered that carelessness and haste, in addition to causing accidents, often results in rendering ammunition unserviceable even when in containers. Ammunition must always be handled with greater regard for safety than general cargo.
8. In the transfer of personnel where water temperatures are low, "immersion suits" should be worn.
9. Whenever practicable, a rescue ship should be stationed astern of ships replenishing at sea for the purpose of rescuing personnel lost overboard.
10. During night replenishment flashlights (life-jacket type) should be pinned to the left breast of each life jacket in use. They are not to be lighted unless the order is given to do so.
11. Plastic police whistles should be issued to each man wearing a life jacket during night replenishments. They are worn on a lanyard around the neck, with the whistle tucked inside the life jacket to prevent fouling in lines or gear.
12. A lifebuoy watch should be stationed in the after part of the ship with a 24-inch buoy fitted with a float light.

9.22. Fueling at sea can be conducted by using either the close-in or span wire rigs. The choice is governed by the kind of ship delivering the fuel and the conditions under which replenishment is made. The close-in and the span wire (formerly Elwood) rigs differ primarily in the method of extending the hose to the receiving ship.

Only fleet oilers are provided with the installations necessary for transfer-

ring fuel by the span wire method. However, it is contemplated that several classes of ships undergoing conversion and modernization in the future will be equipped to fuel other vessels using this method. For the present, transfer of fuel between vessels other than fleet oilers requires the employment of the close-in rig.

9.23. Close-in Rig. The hose in the close-in method of rigging is supported by boom whips and bight lines which lead from saddles on the hose to booms or other high projections on one or both ships. (See Fig. 9.11.)

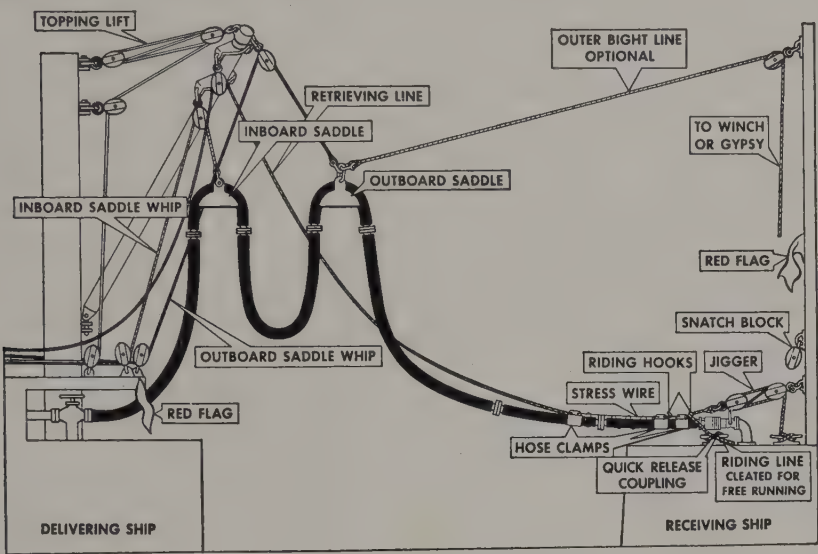


FIG. 9.11 CLOSE-IN RIG FOR FUELING

9.24. Rigging the Oiler for Close-in Refueling. The following is a check-off list that may be used as a guide in making up the hose and lines for close-in fueling.

1. The *hose* (6-inch) consists of the following: Oiler's onboard end, one 50-foot length, collapsible. Inboard saddle section, one 20-foot length, wire-stiffened. Section between saddles, one 50-foot length, collapsible. Outboard saddle section, one 20-foot length, wire-stiffened. Extension, one 50-foot length, collapsible. Outboard section, two 20-foot length, wire-stiffened. (Two hose clamps and hooks are attached to this section approximately 9 and 13 feet from the outboard end.) Total length of hose, 230 feet.

2. The *inboard saddle whip* is of 5-inch manila, 40 fathoms long, fitted at one end with a thimble eye and a 10-inch shackle. This whip is shackled to the inboard saddle and rove through a 14-inch snatch block on the outboard side of the boom head. It is then led to the inboard gypsy head.

3. The *outboard saddle whip* consists of 300 feet of ¾-inch wire rope (6 x 37 high-grade plow steel) or an equal length of 5-inch manila. It is fitted at one

end with a thimble eye and a ⅝-inch shackle. The whip is shackled to the outboard saddle and rove through the block shackled to the pad eye below the head block. The whip is then led forward of the king post and to the drum (wire) or gypsy head (manila) of a winch.

4. An *outer bight line* is used only when fueling vessels larger than destroyer types. It is 5-inch manila 50 fathoms long, with a thimble eye and 1-inch shackle at one end. To the other end is taper-spliced a 15-fathom length of 2½-inch manila, then 15 fathoms of 21-thread manila, and to that 30 fathoms of 6- or 9-thread manila. The thimbled eye of the outer bight line is shackled to the outboard saddle, outboard of the outboard saddle whip.

5. The *retrieving line* consists of 50 fathoms of 3½-inch manila, with a thimble eye and a ¾-inch shackle at one end. The thimble eye is shackled to the hose clamp inboard of the hose messenger and led through a 12- or 14-inch snatch block on the forward side of the boom head, and through a fairlead to the inboard gypsy head. The inboard gypsy head is used alternately to serve both the retrieving line and inboard saddle whip.

6. The hose messenger is a 3½-inch manila line 40 fathoms long, with a thimble eye and a ¾-inch shackle at one end. To the other end is taper-spliced a 15-fathom length of 21-thread and to that 30 fathoms of 6- or 9-thread manila. The thimble eye of the messenger is shackled to the hose at 3-foot intervals. The seizing at the end of the hose should be two turns of 21-thread.

7. The fueling boom should be swung out 90 degrees and topped up so that the head of the boom is just clear of the ship's rail.

8. The hose should be topped up as follows: Two-block the inboard saddle. Top up the outboard saddle to a point just below the inboard saddle. Top up the end of the hose with the retrieving line to a point just below the outboard saddle. Lead the hose messenger to the superstructure deck and fake it down athwartships. The bights of the messenger should not be more than 10 feet long, and each bight should be stopped to the life rail.

9.25. Close-in Fueling Procedures. A 12-inch snatch block, through which the hose line messenger is led, is provided at each fueling station of the receiving ship. This block is placed inboard of the ship's side and about 6 feet above the receiving deck. On receiving ships larger than destroyers, a 14-inch snatch block is secured at the highest convenient point above the point where the hose will be taken aboard. This is used to fairlead the outerbight line, which helps support the outboard hose saddle. A riding line about 3½ fathoms long, made of 4- or 5-inch manila, is provided at each fueling station of the receiving ship. One end of this line is eye-spliced and secured to the hook or shackle of a jigger tackle. The other end is left free but, when the hose is aboard, will be secured to a cleat. When fueling a destroyer, if the Stewart elbow is not used, the end of the hose is shoved into the trunk and lashed securely.

As the receiving ship steadies alongside, heaving lines or line-throwing gun lines are sent over from each station on the delivering ship to corresponding

stations on the receiving ship. By means of these first lines the telephone cables, distance lines, hose line messengers, and outer bight lines are started over. If the oiler has difficulty getting her lines across, the receiving ship may use her own line-throwing guns, when requested to do so by the oiler. As soon as the oiler's telephone jackboxes reach the deck of the receiving ship, connections are made and communications established.

The oiler pays out the hose messenger by hand as the receiving vessel draws it on board. On the receiving ship the messenger is led to the snatch block provided for it and, finally, to a winch; or it is led on deck for heaving in by hand. The oiler pays out the retrieving line and saddle whips, allowing the hose to come across assisted by the outer bight line from the receiving ship (if such a line is being used). As the end of the hose comes on board, the receiving ship cuts the stops securing it to the messenger, one by one, until the riding line hook is within easy reach. The bight of the riding line is then slipped over the riding line hook and the riding line is set taut. The hose end now is ready to be coupled to the receiving ship's hose or to be lashed in the fueling trunk. After this has been done, the messenger is restopped to the hose, removed from the snatch block, and the bitter end is returned to the oiler. The oiler tends the messenger as the ships open or close distance.

If an outer bight line is used the receiving ship takes it to the 14-inch snatch block provided and tends it. As the ships roll, the hose bight may dip in and out of the water unless the outer bight line is used to raise and lower the outboard hose saddle. When the ships roll in opposite directions, the hose will rise up suddenly, and the bight line (as well as the oiler's saddle whip, which is also helping to support the saddle) will stretch out horizontally. If these lines are not slackened immediately, they will break under the strain.

The outer bight line (tended by the receiving ship) and the outboard saddle whip (tended by the oiler) need constant handling by alert and well-trained personnel. Fast-moving winches will have to be used. Winchmen on both ships, working together, attentive to the outboard saddle, should try to keep the two lines in the form of an upright V.

When the outer bight line is not used, the outer hose bight is controlled by the oiler's outboard saddle whip alone.

When fueling is completed, the engineering force on the receiving ship gives the STOP PUMPING signal, disconnects the hose (after a back suction has been taken or the hose blown clear), and lashes closed the necessary valves or replaces the end flanges or hose caps. The hose is eased out on the bight of the riding line. As the outer bight line or hose messenger is being eased out, the oiler heaves in and two-blocks the inboard and outboard saddles. The oiler stops off the inboard saddle whip, removes it from the winch drum, and belays it to a cleat. The retrieving line is placed on the same drum, and with it the hose is hauled aboard. Finally, the receiving ship returns the outer bight line, the telephone and distance lines, and the messengers.

9.26. Span Wire Rigs. In the span wire rig, the hose is extended by use of a single-span wire stretching between the two ships. The hose hangs from trolley blocks which ride along the wire. This permits ships to open out to between 140 and 180 feet. The greater separation is safer, better for station keeping, and conducive to easier maneuvering. These factors not only allow commanders a wider latitude in choosing a fueling course, but they also facilitate the use of antiaircraft batteries should the need for them arise. The span wire method, with its higher suspension, affords protection for the hose in rough weather. With this method, the hose may be rigged in two different ways—the manila rig or the all-wire rig.

9.27. Manila-Rigged Span Wire. The manila rig is simpler than the all-wire rig, but requires more personnel at each station during the fueling operation.

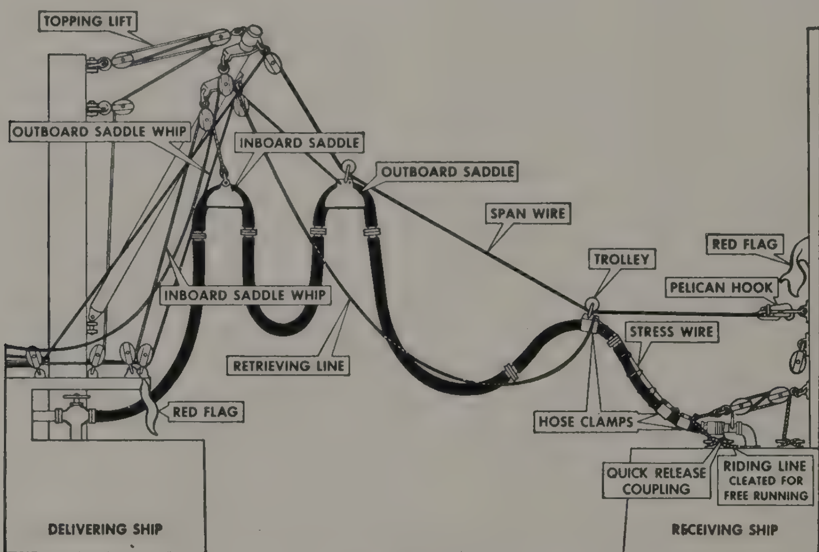


FIG. 9.12 SPAN WIRE RIG FOR FUELING

The following is a guide to be used in making up the hoses and lines for fueling by the manila-rigged span wire method. (See Fig. 9.12.)

1. The *hose* (6 inch) consists of the same number of sections and is joined in the same way as the hose in the close-in rig. The riding line hook is attached to the hose 9 feet from the outboard end. For destroyer fueling, manila straps are used to help support the outboard end of the hose at the riding hook and at the bitter end.

2. The *inboard* and *outboard saddle whips* are made up and rigged as in the close-in rig.

3. A *retrieving line* of 4- or 4½-inch manila, 61 fathoms long, fitted at one end with a thimble eye and a ¾- or ⅞-inch shackle, is fairled through a 12- or

14-inch snatch block on the forward side of the boom head. From there it goes through a fairlead to the inboard winch gypsy head.

4. The hose line *messenger* is 60 fathoms of 4- or 4½-inch manila fitted at one end with a thimble eye and a ⅞-inch shackle. To the other end is taper-spliced a 15-fathom length on 2½-inch manila, then 15 fathoms of 21-thread. Added to that is 30 fathoms of 6- or 9-thread manila. The messenger is shackled to a fitting on the riding hook hose clamp and is stopped to the hose with 21-thread at intervals of 3 feet. A wire pendant connects the riding hook hose clamp with the outboard hose clamp to prevent the hose from taking any strain from the riding line.

After the riding line is secured, the messenger is unshackled and returned to the delivering ship by means of a hose messenger retrieving line. By retrieving the hose messenger during the fueling operation, the time required for the breakaway is reduced, and preparation for fueling the next ship is expedited. The retrieving line is 50 fathoms of 21-thread.

5. The *span wire* is 6 x 37 high-grade plow steel, ¾ inch in diameter and 450 to 600 feet long.

The wire boom falls are single whipped and the span wire is reeved through two trolley blocks and (if used) the free trolley. To the undercarriage of each trolley block is attached a swivel and a shackle.

6. One *trolley block* is connected to the outboard saddle slings and the other to the hose clamp. When a free trolley block is used, it is connected to a manila strap and ring about 10 feet from the outboard end of the hose.

7. The *fueling boom* is swung out 90 degrees and topped up so the head of the boom just clears the ship's rail.

8. The *retrieving line* is shackled to the hose clamp so it is outboard of the span wire trolley block and inboard of the wire pendant.

9. The hose is topped up as in the close-in rig.

10. A ⅞-inch diameter pelican hook is fitted to the span wire eye. The span wire is led to the superstructure deck level and the span wire is stopped securely to the hose messenger 200 feet from the inboard end of the hose.

There should be seizings 5 and 8 feet from the pelican hook. One method recommended is to form bights of ¼-inch wire rope at these points by tucking the ends of the ¼-inch wire into the span wire several times. The bights should be about 3 inches. The messenger is stopped to these bights with flat seizings of about four turns of small stuff. The stop securing the pelican hook to the messenger should be run through the long link of the pelican hook, and the hook should be allowed to hang a few inches below the messenger to facilitate cutting the stop.

9.28. Rigging the Receiving Ship for Span Wire Rig. At each fueling station on the receiving ship there must be the following:

1. A 1-inch tie-in pad eye for the span wire pelican hook, located above and approximately in line with the point at which the hose is to come aboard.

2. Another pad eye or wire strap (at least 6 inches below the tie-in pad eye) on which a 12-inch snatch block is placed to fairlead the hose messenger.

3. A third pad eye below the second, for shackling the end of the hose riding line.

9.29. Span Wire Procedures. The lines are passed in the same manner as in the close-in method. On the receiving ship, the hose messenger is led through the 12-inch snatch block, and as much of the messenger as possible is run in by hand. Then it may be taken to a winch. Aboard the oiler the messenger is payed out by hand, and the stops holding the messenger are cut in sequence as rapidly as necessary. The span wire is payed out from the drum as the messenger hauls it across.

When the span wire comes aboard the receiving ship, the pelican hook is made fast to the tie-in eye, and the stops securing it to the messenger are cut. The oiler now begins to tend the span wire, making sure that a good catenary is maintained at all times. The span wire should never be slacked off enough for the hose to touch the water.

When the hose messenger is cut free from the span wire, the receiving ship resumes heaving it in while the delivering ship pays out on the retrieving line and saddle whips. The saddles should be positioned so the span wire will carry the weight of the hose, but the saddle whips can be used to control the height of the hose.

When the hose end comes within easy reach of the men on the receiving ship's deck, the stops seizing it to the messenger are cut, one by one, until the bight of the riding line can be slipped over the riding line hook. Then the end of the hose is tended and controlled by the receiving ship, and the messenger is returned to the delivering ship where it is made up for the next receiving ship.

When all is secure, the receiving ship opens the hose valve and notifies the oiler to begin pumping.

On the receiving ship upon completion of fueling the valve is closed and the hose uncoupled. Then, by using the riding line, the end of the hose is eased out clear of the ship's side. The oiler two-blocks the inboard and the outboard saddles, stops off the inboard saddle whip, removes the whip from the winch gypsy head, and belays it to a cleat. The retrieving line is then placed on the winch gypsy head, and the hose is hauled aboard the oiler. When the hose has been retrieved, the span wire is slackened by the oiler, and the receiving ship trips the span wire pelican hook and eases out the end of the span wire on the bight of an easing out line rove through the long link of the pelican hook. The span wire pelican hook is not to be tripped until the span wire has been slacked.

The oiler then hauls in the span wire and the telephone and distance lines to complete the operation.

9.30. Safety Precautions While Fueling. The span wire is secured to the winch drum by one wire clamp. In case of a casualty or other emergency caus-

ing the ships to veer apart, the wire must be payed out from the winch drum to the securing clamp. As the strain increases, the wire will slip free of the clamp and drop over the side with minimum possibility of casualties to gear and personnel.

A $\frac{5}{8}$-inch shackle must be used for attaching the span wire to the pelican hook and for securing the stress wire between the hose clamps. This shackle acts as a safety link which parts before the full breaking load of the $\frac{3}{4}$-inch wire can be imposed on the boom, thereby minimizing the possibility of failure of the boom.

9.31. All-Wire Span Wire. The all-wire span wire rig for fueling at sea is used with a wire saddle line and a wire retrieving line. This can be used only if enough winches are installed at the stations to be rigged. A minimum of three winch drums is required.

The all-wire rig can be used to replenish destroyers or larger. When fueling a DD, however, a 10-foot section of 4-inch hose is attached to the outboard section of 6-inch hose, whereas a quick release coupling is used for larger ships.

Part II

SHIPHANDLING

10

General Principles of Ship Control

Shiphandling is the highest form of seamanship. It is an art because the forces involved are so many, so variable, and so different from ship to ship, under all conditions of wind and sea.

Many naval and merchant ships are twin or multiple screw and some have twin rudders. The ability to handle these ships can be assisted by a thorough understanding of the forces set up in a single-screw ship when the propeller revolves, the rudder is "put over," and the ship moves through the water. We shall discuss, first, the propeller and rudder forces in a single-screw ship and then go on to consider these forces in a twin-screw ship.

10.1. Forces that Affect Maneuvering in a Single-Screw Ship.[1] The action of a propeller in a single-screw ship brings into play many unsymmetrical forces. In order to understand these, it is necessary to have some idea of the manner in which a propeller generates forces. As a ship moves through the water, she experiences skin friction due to the viscosity of the water and tends to drag some of the water with her. If we measure the velocity of this water relative to that of the ship at increasing distances from the hull, we find that close to the hull the relative velocity is small because the water clings to the ship. The relative velocity increases as the distance from the hull increases until a point is reached where the water has no motion with respect to the surrounding sea. Its velocity relative to the ship equals the velocity of the ship. The boundary layer includes the water from the hull to the point where the relative velocity equals that of the ship. The width of this layer varies in some cases from zero at the bow to several feet near the stern. The net effect is that the boundary layer, a body of water, is given a forward motion by the passage of the ship.

Owing to this frictional drag upon the surrounding water, there is found aft, in the vicinity of the ship, a following current or wake called *the frictional wake*. The frictional wake is, in most cases, greatest at the surface in the vertical plane through the keel and abaft the ship. It decreases downward and outward on each side, as shown in Fig. 10.1. Streamline and wave patterns affect the velocity of the wake, but their effect is small.

The propeller revolves in this wake. Since the wake water is moving forward relative to the sea, the propeller, in effect, is advancing into a moving body

[1] Based, in part, on *Propeller Action in a Single Screw Ship*. Courtesy of the Director, David Taylor Model Basin.

of water. Its speed is less than that of the ship. Thus, if a ship is moving at 15 knots and dragging a wake with it at 3 knots, the propeller is only advancing at 12 knots *relative to the wake.* The ratio of the wake speed to the ship's speed is called the *wake fraction:* in this case $3/15 = 0.20 = W$.

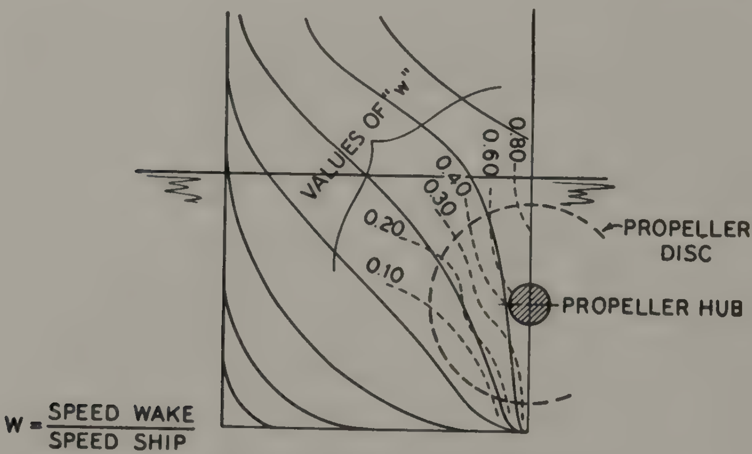


FIG. 10.1 WAKE DISTRIBUTION FOR SINGLE-SCREW SHIP

The speed of the advance of the propeller through the wake is given by

$$V_A = V(1 - W), \text{ where } V = \text{ship's speed in knots}$$

In the preceding case,

$$V_A = 15(1 - 0.20 = 15 \times 0.8 = 12 \text{ knots}$$

The wake speed of 3 knots is only an average speed and actually varies from place to place. Behind shaft struts, skeg, or rudder, the wake speed may equal that of the ship. It is this variation in wake pattern which causes the unsymmetrical propeller forces.

The wake pattern has been measured on many models. A typical wake distribution appears in Fig. 10.1. The curves on the right side are similar to those on the left. The figure shows by contours of W values the distribution of the wake velocity (the fore-and-aft components) over the propeller disc. Along the line labeled $W = 0.60$, the speed of advance of the propeller through the wake is only 40 percent of the ship's speed. See example above.

In addition to the fore-and-aft motion, the water moving aft alongside the ship has an upward and inward flow under the counter due to the general rise of the water as the stern moves forward.

Analysis of Propeller Action. The maximum thrust is developed at about 0.7 of the radius from the centerline of the shaft. We shall discuss the forces generated at this point. The velocity of the blade section relative to the water is the resultant of two component velocities:

1. A forward motion through the water at velocity V_A or ship speed minus wake velocity.
2. A rotational motion of the propeller which is given by $2\pi RN$. R is the radius under consideration (0.7), and N is revolutions in a unit of time.

The resultant velocity of the water V_0 is a combination of the forward and rotational motions. (See Fig. 10.2.) The effect of V_0 striking at the angle of attack α is to develop lift and drag just like the forces on an airplane wing.

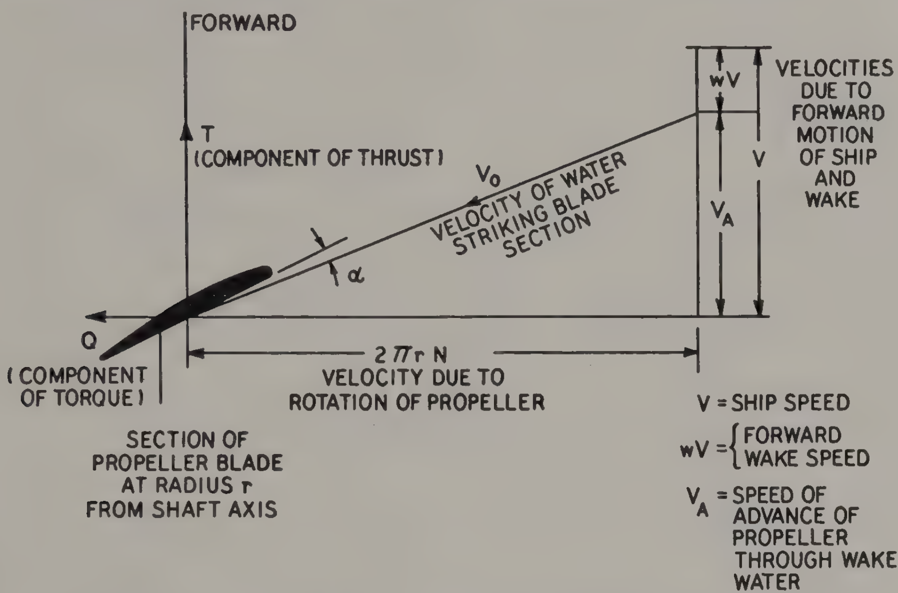


FIG. 10.2 SIMPLIFIED VELOCITY DIAGRAM FOR PROPELLER BLADE SECTION

The direction of V_0 to the face of the blade section at the angle of attack produces forces which can be resolved into two components, a fore-and-aft force, the thrust T, and a torque Q. The former, T, propels the ship and the latter, Q, *generates a reaction or transverse force through the shafting which tends to force the stern to port or starboard.* If we look at Fig. 10.2 in another way, we could consider V_0 as one of the forces, all acting in the direction of the arrow and on the after surface of the blade. In fact, the forces act on both sides of the blade. If the angle of attack α between V_0 and the surface of the blade is small, the component forces T and Q will be small. If the angle is large, i.e., when WV, the forward wake speed, is great, the force V_0 will strike the surface of the blade at a more effective angle. T and Q will be large. WV, the wake speed, varies as shown in Fig. 10.1, which explains the unsymmetrical forces acting on the hull. The amount of work done by each blade of the propeller will vary with its position in the disc.

There are four regions where the maximum change in force occurs:

1. As blade A (Fig. 10.3) approaches the vertical point, Fig. 10.1 shows it will pass through a region of relatively high wake speed and therefore low values of V_A (Fig. 10.2 shows that α will increase as V_A drops in value. V_0 will act on the blade at a larger, more effective angle of attack. T and Q will increase.) The increase of the torque Q *reacts* through the shafting on the stern of the ship, forcing it to port with a right-hand propeller. If we revert to our explanation of V_0 above, it is clear the V_0 is acting from starboard to port against the rear side of the blade A. Because a right-handed propeller is being considered, V_0

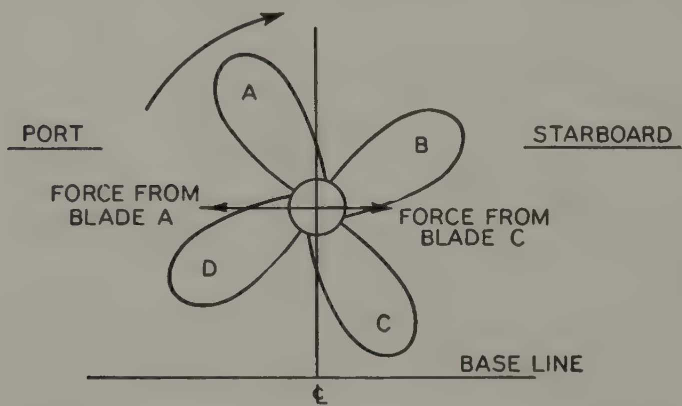


FIG. 10.3 VIEW FROM ASTERN SHOWING FORCE ON SHAFT AXIS

will have two components; T, the thrust propelling the ship through the water; and Q, which generates a transverse or athwartship *force* now directing the stern to port.
2. Blade C will pass through an area opposite to that of blade A. A transverse force to starboard will be exerted. (But as the wake speed in the lower part of the disc is much less than in the upper, the angle of attack is smaller than on blade A, and the force to starboard will not be as great as that to port. The resultant force of these two forces is to port.)
3. Blade B will move downward against the upward flow of water under the counter. This flow is equivalent to an increase in N in the formula $2\pi RN$. The angle of attack α, the velocity, thrust, and torque increase.
4. Blade D moves up with the flow and experiences a decrease in the above factors.

It is clear that B overbalances D, and the ship's head tends to fall off to port. There are two more factors that affect the steering of the ship:

1. The propeller imparts a helical motion to the slip stream which impinges on the rudder even when amidships. That part of the helical slip stream

above the axis of the propeller tends to move the stern to starboard, and the part below the axis tries to move the stern to port. The resultant force depends on the area of the rudder above and below the centerline of the shaft and the uniformity of the slip stream.

2. The next factor is the submergence of the propeller. If the ship is in ballast or at light displacement, the propeller may break surface, causing a decrease in the transverse effect of blade A. When the ship has little or no speed, blade A which is near the surface may draw air and again decrease the transverse force.

The ship is therefore subject to several opposing, variable forces. Her actual behavior will depend on the magnitude of these forces. General experience shows that many single-screw ships with a right-hand propeller turning ahead tend to fall off to port. There are exceptions, and no hard and fast rule can be laid down. Observe your own ship.

10.2. Getting Underway. With the ship stationary or just starting to move, the wake does not exist or is negligible. The top blade A may break the surface and thus lose some of its usual transverse force to port. If it does not break the surface, air may be drawn down with the same effect. The lower blade still acts to force the stern to starboard. The rudder, even when amidships, receives the helical slip stream at an effective angle high up on the port side. If the rudder has a larger area above the axis of the propeller than below, that force tends to move the stern to starboard. The result of these forces may be that the stern will move to starboard.

When backing, the forces due to blades A and C are reversed. Blade A may break the surface, but, regardless, C, acting to port, will predominate. There is no helical slip stream thrown against the rudder. Most of the water which passes through the propeller disc comes from the free surface, and the rudder exerts no steering force until the ship gains sternway. The upper part of the discharge flow from the propeller strikes the starboard underwater body of the ship at a good angle. The lower part strikes the keel on the port side at a poor angle. It is probable that the force due to the upper part predominates, and the result of these forces tends to push the stern to port.

10.3. Handling Ships with Controllable Pitch Propellers. An increasing number of small ships, such as the new LST's, tugs and the Navy's latest non-magnetic ocean minesweepers (MSO), have controllable pitch propellers. The blades of the propellers are rotated by a hydraulic mechanism in a plane parallel to that of the propeller shaft as described in Chapter 4. Thus the blades can be adjusted to take more or less bite, or can be reversed in pitch. It is this latter feature particularly that adds maneuverability; the new minesweepers, for example, can be stopped in less than two ships lengths when going ahead full power.

The forces acting on the controllable pitch propeller are the same as those described above for conventional propellers. The shiphandler uses his rudder and engines in the conventional way except, instead of speeding up, slowing,

or reversing his engines, he adjusts or reverses the pitch of his blades by a control mechanism on the bridge. Since the response to change in propeller blade pitch is instantaneous the shiphandler must become accustomed to this disappearance of dead time when backing. Another novelty to the seaman trained to handle conventional ships will be his ability with controllable pitch propellers to move the ship quickly with high power. This is done by keeping the shaft revolutions high and the propeller pitch low. An increase in propeller blade pitch then applies power to the ship very suddenly.

10.4. Steering a Twin-Screw Ship, Single Rudder. A twin-screw ship has two propellers, one on either side of the centerline. Generally, they are out-turning, i.e., the starboard one is right-handed and the port one left-handed. They turn in opposite directions to balance the propeller forces and enable the ship to steer a straight course with no rudder.

A multiple-screw ship normally has four propellers, two on a side outturning and so controlled that those on a side go ahead or astern as a unit. As the action of a multiple-screw ship is similar to that of a twin-screw ship, only the latter will be discussed.

The steering of a twin-screw ship is considerably simpler than that of the single-screw ship. It will be found that the strong tendency of the single-screw ship to back stern to port does not hold with the twin-screw, and that the latter backs with equal facility in either direction, barring the effect of wind, waves, and currents.

The various forces affecting the action of the single-screw ship are still present to a degree in the case of a twin-screw. In many cases they are considerably less because the forces from one screw are balanced by similar but opposite forces emanating from the other screw. In addition, there is a new force due to the movement of the screws around the centerline. It will readily be seen that with one screw going ahead and the other astern, there results a turning moment that tends to throw the *bow* to the side of the backing screw.

One powerful force should not be overlooked. It is the momentum of the ship, ahead or astern, acting through the center of gravity. If a twin-screw ship is going ahead and one screw is backed, two opposing forces are set in motion, namely, the force of the backing screw acting in one direction at a certain distance from the centerline and the weight of the ship acting in the opposite direction. These are in addition to the forces due to the action of the wake on the rudder if it is "put over."

The steering of the twin-screw ship will be considered under the following headings, no wind or sea:

1. Ship and Screws Going Ahead.
2. Ship Going Ahead, Screws Backing.
3. Ship Going Astern, Screws Backing.
4. Ship Going Astern, Screws Going Ahead.
5. One Screw Going Ahead, Other Screw Backing.

10.5. Ship and Both Screws Going Ahead, Single Rudder. In this case, with the rudder amidships the ship will steer a steady course. The transverse forces of the two propellers are equal and opposite in direction. As the shafts are offset equally, no turning moment is felt.

When the rudder is put over, it will receive some of the discharge flow from the propeller on that side but not as much as in a single-screw ship. The principal force which turns the ship is that set up by the wake against the forward side of the rudder.

If one screw is stopped with the rudder amidships, the turning moment of the revolving screw will take charge, and the ship will turn toward the side of the stopped screw. The discharge flow of the revolving screw does not strike the rudder.

10.6. Ship Going Ahead, Both Screws Backing, Single Rudder. The steering effect of the rudder is the only force turning the ship from a straight course. All other forces are equalized. The effect of the rudder is reduced as the headway is lost until there is no steering control when the ship is stationary.

If one screw only is backing and the other stopped with headway on, the turning moment of the backing screw added to the momentum of the ship going ahead will swing the stern away from the backing screw. If there is deadwood forward of the screw, the discharge flow will strike the underwater body and increase the swing.

10.7. Ship Going Astern Both Screws Backing, Single Rudder. If the rudder is amidships, the various forces are equalized, and a straight course can be steered. If the rudder is put over, the pressure of the water that you are backing into against the back side of the rudder will enable a course to be steered. However, most of the water which passes through the screws comes from the free surface and thus has little effect on the rudder.

If one screw is stopped, the turning moment of the backing screw is added to the effect of the rudder when it is put over away from the revolving screw. The swing may be slowed or stopped if the rudder is put over toward the screw. The effect of the rudder is to counteract the effect of the screw, and how effective it is will be dependent upon the size of the rudder and speed of the engine.

10.8. Ship Going Astern, Both Screws Going Ahead, Single Rudder. The ship will respond to the rudder, i.e., a left rudder will throw the stern to port unless excessive sternway is on. The transverse forces of the screws will be equalized. The steering effect of the rudder when going astern will be reduced gradually as the ship loses headway, until all steering control is lost before the ship has lost sternway. This is because the discharge flow from the propellers will interfere with the flow of water against the back of the rudder.

10.9. Ship Stationary, One Screw Going Ahead, Other Screw Backing, Single Rudder. The rudder will have little effect until head or sternway has been gained. The turning moments of the two screws will be additive, but they may not be great when the shafts are close together. If the ship has no dead-

wood, she may turn easily. In narrow waters the two screws should be operated as such speeds that the ship does not gain head or sternway when going ahead and backing at one- or two-thirds speed. This balancing of forces will enable the captain to move the ship ahead or astern as desired by varying the speed of the backing or ahead engine. As a general rule with one engine ahead the same amount as the one astern, the ship will slowly make headway. The rudder may be used to increase the swing when some steerageway has been gained.

10.10. Twin Rudders on Twin- and Multiple-Screw Ships. Twin rudders are now installed on many vessels, large and small, and vary in position, shape, and size. The rudders on destroyers receive most of the upper half of the discharge flow of the propellers when going ahead. The lower half passes under the rudder. The installation of twin rudders has improved the maneuverability of ships. The general rule when handling twin-screw destroyers with one rudder is to order the proper rudder after the ship has gained head or sternway. The installation of twin rudders has changed this rule, and the shiphandler should now order right or left rudder before the engines are moved. The rudder should be put over to take advantage of the discharge flow from the ahead propeller. This flow acts against the forward side of its rudder and thus creates a powerful force to turn the ship.

The improved turning characteristics of destroyers are appreciated when turning in narrow channels and going alongside a nest or tender where large angles of approach must be used. The maneuvers to shove off from a nest, tender, or pier under awkward conditions of wind and tide are facilitated too.

The key to all these ordinarily difficult maneuvers is the decisive effect of the discharge flow from the ahead propeller on the rudder astern of it. If the other propeller must be operated astern, it may do so without affecting the turn adversely because the water passing through its disc comes from the free surface and does not impinge on the rudder to any great extent. Hence, the ship can be turned to port from dead in the water, for instance, by ordering the "left full rudder, ahead two-thirds speed" on the starboard engine and "back, two-thirds speed" on the port engine. The speed of the port engine can be varied thereafter to allow the ship to gain steerageway as and if desired. The rudder and the starboard engine need not be changed until the turn is completed.

10.11. Turning Characteristics. The standard method of finding any ship's turning characteristics is to turn her in a number of complete circles under varying conditions and to record the results for each turn. The variables used are: right or left rudder of various degrees; steady speeds of different value; and differences in draft and trim. When taking turning data, the effects of wind and sea are noted and allowed for. Most changes, of course, are not as much as 360 degrees, but by studying the complete turning circle the ship's behavior for turns of any extent can be determined. In considering the track actually followed by a ship during a turn, certain terms must be defined.

These terms may be understood more easily by a simultaneous study of Figs. 10.4 and 10.5. Figure 10.4 shows actual turning circles of the *U.S.S. New Mexico.* One figure is the circle made at 21 knots with 35 degrees right rudder; the other, the circle made at 10 knots with 10 degrees left rudder. Figure 10.5 illustrates some differences in the turning curves made by ships of different lengths and characteristics.

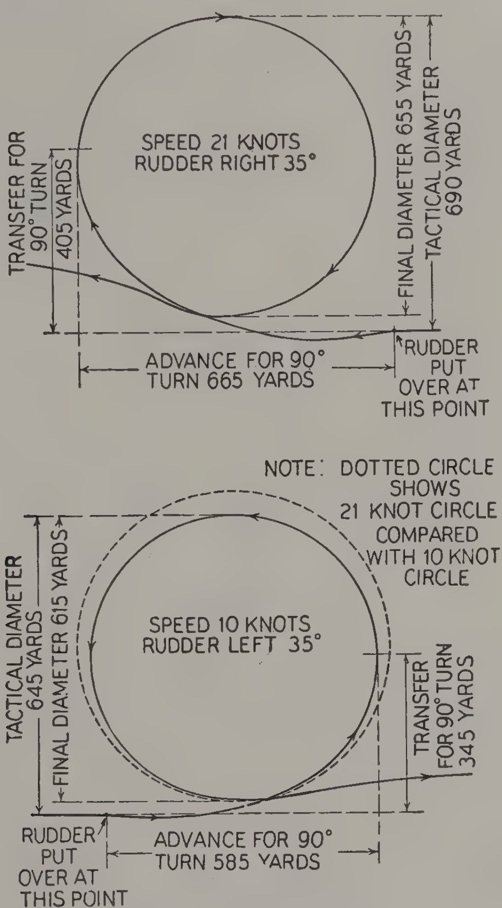


FIG. 10.4 TURNING CIRCLES

10.12. Definitions. *a. Turning Circle.* The path followed by the *pivoting* point of a ship in making a turn of 360 degrees or more. For the ordinary ship the bow will be inside and the stern outside this circle.

b. Advance. The distance gained in the direction of the original course. The advance will be a maximum when the ship has turned through 90 degrees.

c. Transfer. The distance gained at right angles to the original course when the ship has turned through 90 degrees.

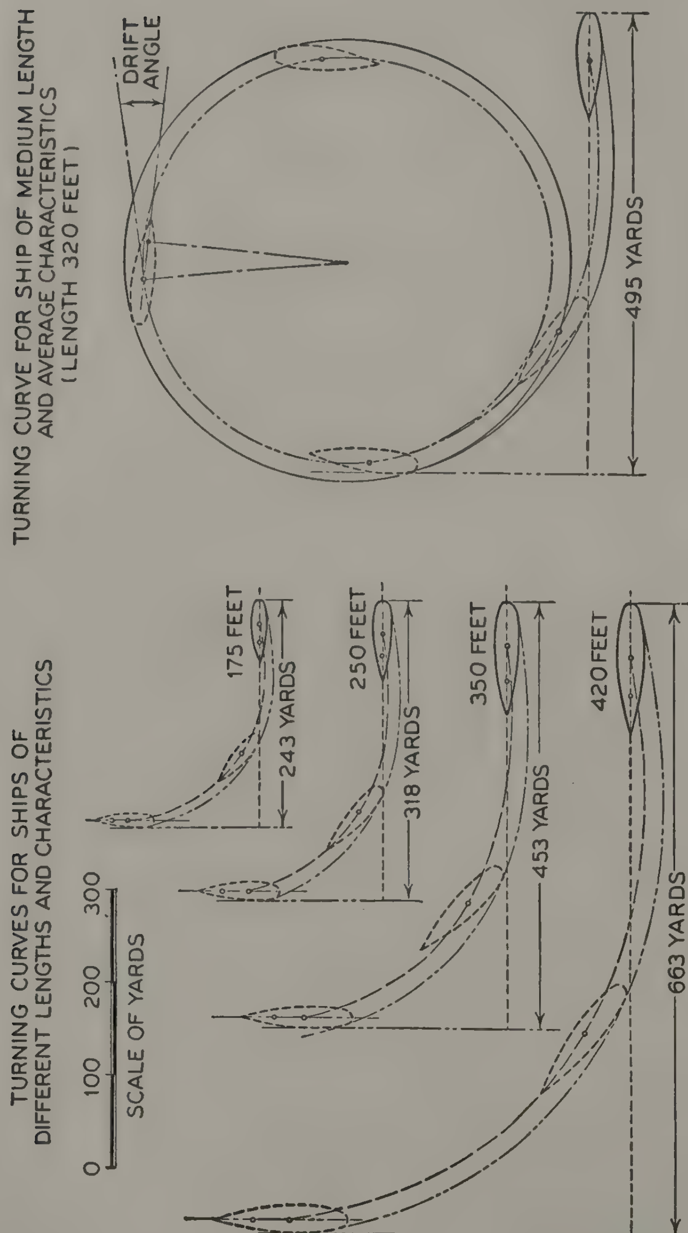


FIG. 10.5 TURNING CURVES

d. Tactical Diameter. The distance gained to the right or left of the original course when a turn of 180 degrees has been completed.

e. Final Diameter. The distance perpendicular to the original course between tangents drawn at the points where 180 and 360 degrees of the turn have been completed. Should the ship continue turning indefinitely with the same speed and rudder angle, she will keep on turning in a circle of this diameter. It will always be less than the tactical diameter.

f. Kick. The distance the ship moves sidewise from the original course away from the direction of the turn after the rudder is first put over. The name is also applied to the swirl of water toward the inside of the turn when the rudder is put over to begin the turn.

g. Drift Angle. The angle at any point of the turning circle between the tangent to the turning circle at that point and the keel line of the vessel.

h. Pivoting Point. That point about which the ship turns when the rudder is put over.

The turning circle is the path followed by the pivoting point during the turn. The pivoting point is in the horizontal centerline of the ship, and its position on that line depends on the shape of the underwater hull and especially on how much the after deadwood is cut away. The pivoting point moves forward if the ship is trimmed down by the head and aft if it is down by the stern. This characteristic is illustrated by the standard motor launch. When light it pivots well aft on account of the weight of the engine, and when heavily laden it pivots well forward. The pivoting point may also move aft along the keel line to some extent if the ship is deep in the water and forward if she is light. It is normally in the forward one-third length of the ship. When its position is once determined, it does not vary enough in the ordinary ship under different conditions of load and trim to cause any difficulty in ship handling.

10.13. Other Forces Affecting Turning. Every seaman knows that the wind affects turning. The freeboard and superstructure act as a sail area whose effect must be considered, especially at low speeds. In most ships there is more superstructure forward than aft, and even in cases where it is equally distributed, there is usually a higher freeboard at the bow than at the stern. The general effect of this construction is that the forward part of a ship acts as a headsail. This has some effect on a ship going ahead but is very important in backing. A ship when backing will back into the wind almost invariably. The propeller acts as a pivot, and the bow and superstructure under the pressure of the wind will fall off. The stronger the wind, the stronger the tendency to back into the wind. This tendency can be used to facilitate a turn when maneuvering in shallow waters.

The condition and relative direction of the sea affect both the progress and steering of the ship by their effect on the underwater body. Any sea forward of the beam will retard the motion of the ship over the ground to a greater or less extent, while any sea from abaft the beam will accelerate it. The general effect of the sea on steering is to cause a ship to seek the trough. If the sea is

on the bow or quarter, it may be necessary to carry a definte amount of either right or left rudder in order to maintain the course. This will cause some loss of speed on account of the rudder effect. In a gale it is usually necessary to slow down when "bucking" a heavy sea. The slow engine speed opposed to the force of the waves causes the ship to lose steerage way. Under these conditions the tendency of the ship to "fall off" into the trough is very pronounced. Full ahead on one engine and one- or two-thirds astern on the other will usually straighten her up. There may be anxious moments, however. With a following sea the tendency of the ship is to yaw, and an excessive amount of rudder may be needed to keep her steady. This excessive rudder will slow her down and may counteract the effect of the following sea in increasing her speed over the ground.

Current affects the underwater body of the ship. It is especially important because its existence may not always be realized. Known ocean currents may be shifted, accelerated, diminished, or even reversed by winds blowing steadily in one direction over a long period of time. Currents in harbors, straits, and bays are caused by the action of the tides. The currents at the entrances to certain harbors (the Golden Gate) are strong at times and run at an angle with the entrance course. The current may be reduced or reversed by the tide. The direction and probable force of currents in ports and along the coasts may be determined approximately by the study of tide tables and current charts, but every effort should be made to verify the data found in these publications because the effects of wind and weather may make them inaccurate. Observation of the shape of the shore line and of the direction in which buoys and other anchored navigational aids are leaning will give a good check on the force and direction of the current running at any given time.

The general effect of a current on the underwater body of a ship is to move her bodily in the same direction in which the current is running. When turning in a current, the ship, at the completion of the turn, may be well down in the direction of the current from her position when the turn was started. When held at any point, as by an anchor, the ship usually assumes the position where the current has the least underwater area on which to act. For this reason, an anchored ship heads into the current unless the wind or sea is strong enough to overcome its effect. For the same reason, a ship at anchor will swing with the change of the tidal current. By means of spring lines, current can be used to cant a ship or to move her toward a dock. Steering is always easier when heading into a current than when going with it, except in narrow channels.

Shallow water will modify the normal action of screws and rudder in steering or turning a ship. She may be sluggish in answering her rudder or she may take a sudden sheer to one side. High speeds can be made in shallow water by the use of excessive power, but large waves are formed by the turbulence which causes destruction to shipping and water-front facilities. The best seamanship in harbors and rivers is constant watchfulness, foresight, slow but

steady speed, having an anchor ready for letting go, and some consideration for other craft.

10.15. Casting in a Narrow Channel. The expression to *cast* means to turn a ship in her own water. Ships turn in this manner when getting under way together in a crowded anchorage and when headed in the wrong direction. Single vessels in restricted anchorages often have to turn in their own water too because of nearby anchored vessels or a restricted maneuvering space.

The problem of turning twin-screw ships and a single rudder is not a difficult one. Go ahead on one engine and back on the other, using the rudder when head or sternway has been gained. If the ship is fitted with twin rudders which are directly behind the propellers, order *"hard over"* rudder before going ahead on one engine. Back the other engine at such speed as necessary to prevent headway or sternway being gained.

Single-screw ships can be turned quite easily in light winds in restricted waters. Take advantage of the tendency of most ships to back to port. The first move is to go ahead full with hard right rudder but reverse the engines before much headway is made. Shift the rudder after headway has been lost and back down a short distance and then go ahead *full*. The rudder should be ordered *right full* before the engines ahead begin to turn over. In stronger winds it is advisable to turn so that the tendency to back into the wind can be used to increase the turn.

Most seamen know that an anchor can be used to facilitate and expedite a turn in a restricted space. In these days of steam and electric windlasses, anchors can be hove in without any delay or effort. High-powered vessels generally use their twin screws and powerful engines to turn in places where a single-screw, low-powered steamer uses an anchor.

The anchor is dropped underfoot at short scope. If low powers are used, the anchor will drag somewhat, but the strain on the chain will not be injurious. The engines can be operated ahead and astern as before, but only slow speeds should be used and little steerway gained. The turn should be made to starboard by pivoting on the anchor when going ahead and by the tendency of the stern to swing to port when backing. A careful check of the chart should be made to ensure that a dragging anchor does not foul a submarine cable.

10.16. Navigating in Narrow Channels.[1] A ship will be set off the nearer bank when proceeding along a straight, narrow channel, especially if the draft of the ship is nearly equal to the depth of the water. This effect is particularly noticeable in narrow reaches with steep banks such as certain sections of the Panama Canal and is called *bank cushion*. As the ship moves ahead, the wedge of water between the bow and the nearer bank builds up higher than that on the other side, and the bow is forced out sharply. The suction of the screw, especially with a twin-screw ship, and the unbalanced pressure of water on the quarter lower the level of the water between the quarter and the near

[1] Based on *Ship Handling in Narrow Channels* by Lt. Comdr. Carlyle J. Plummer (T) U.S.C.G.R. Courtesy Cornell Maritime Press, New York.

bank and force the stern toward the bank. This is called *bank suction*. The combined effect of bank cushion and bank suction may cause the ship to take a sudden and decided sheer toward the opposite bank. If a single-screw steamer traveling at very low speed with her starboard side near the right bank takes such a sheer, she may be brought under control by going ahead full with right full rudder. The added steering effect may overcome the bank suction. A twin-screw ship under similar conditions has a fair chance to recover from such a sheer by going ahead full on the port engine, stopping or backing the starboard screw, and putting the rudder full right. Should the sheer carry the ship across mid-channel, the starboard anchor should be dropped and snubbed if necessary. All engines should be reversed as the first anchor is dropped.

10.17. Turning in a Bend. There are several factors which affect a ship trying to turn in a sharp bend in a narrow channel. Two of these have been described, *bank suction* and *bank cushion*. Both are strong when the bank of the channel is steep; they are weakest when the edge of the channel shoals gradually and extends into a large shallow area. The tendency of the ship to continue along her original course when the rudder is put over will be felt in the shoaling case. If the bank of the channel is abrupt and the ship deeply laden, a bank cushion will act against the tendency to continue on her course. The river or canal currents are strongest *in the bend*, and there may be eddies or counter currents on the lee side of the point. Turning in a bend requires a knowledge of how these forces act. Use the forces which are favorable and avoid those which are opposed.

A head current is the safest because a ship can be stopped very quickly, but a following current enables the ship to proceed at good speed with very little speed on the engines. Bank suction increases with engine speed. Bank cushion increases with the ship's speed. The force of the current against the quarter can be used to turn the ship; therefore it is advantageous to proceed with the current.

If the current is ahead, the best position to start the turn is from the middle of the channel. The eddy under the point and the increased current in the bend are both avoided. Proceed at a very slow speed over the ground so that the ship can be stopped quickly by the engines and the current, and perhaps an anchor or two.

There are three choices in *making* a sharp bend with a following current:

1. *Hug* the point.
2. Stay *in the bend*.
3. Proceed on the bend side of the middle of the channel.

If the ship *hugs* the point (Fig. 10.6) A, the helmsman will require a small amount of rudder toward the bank to steer a straight course. Less rudder will be necessary as the channel begins to bend and the ship moves away from the bank. This signal "less rudder" is a great help in determining when to begin

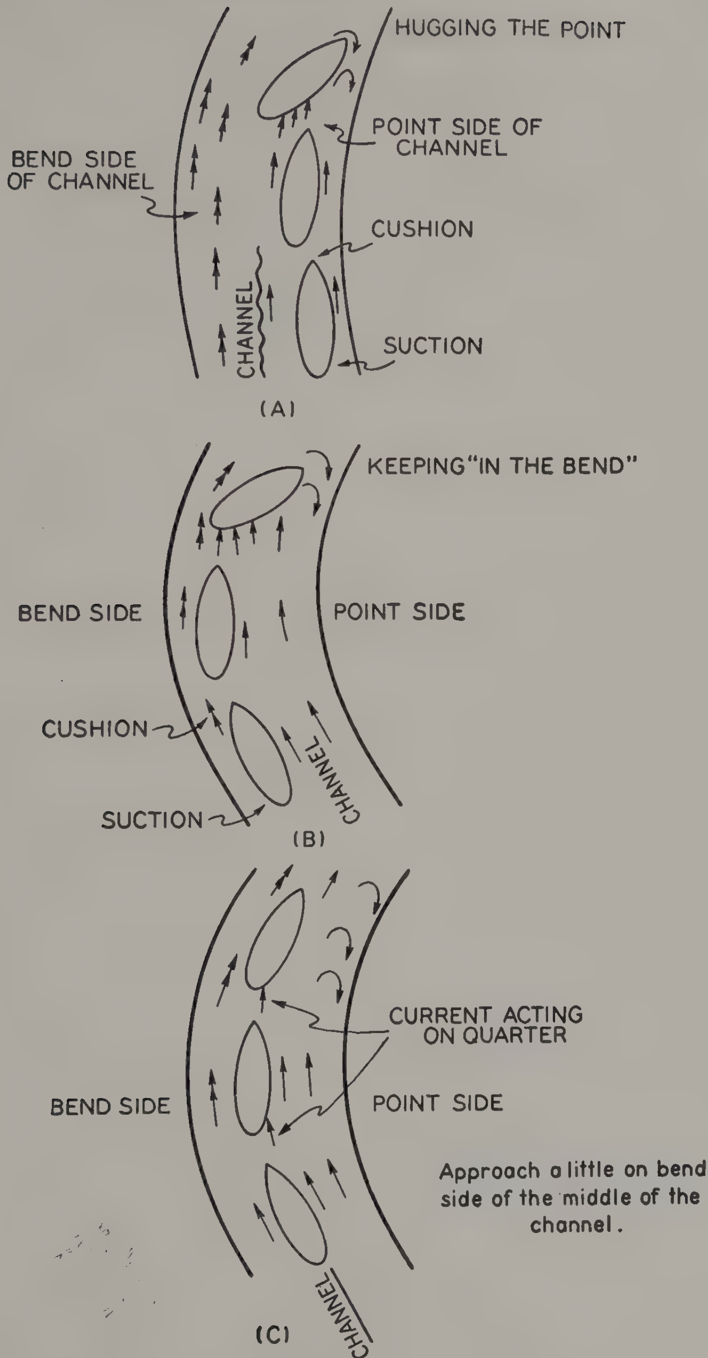

HUGGING THE POINT
POINT SIDE OF CHANNEL
BEND SIDE OF CHANNEL
CUSHION
CHANNEL
SUCTION
(A)
KEEPING "IN THE BEND"
BEND SIDE
POINT SIDE
CUSHION
CHANNEL
SUCTION
(B)
CURRENT ACTING ON QUARTER
BEND SIDE
POINT SIDE
Approach a little on bend side of the middle of the channel.
CHANNEL
(C)

FIG. 10.6

the turn in clear as well as in foggy weather. However, slack water or eddies may be encountered around the turn. These may make it very difficult to prevent a sheer toward the near bank, particularly in shallow water when laden. The stern may feel the current under the quarter and thus increase the sheer.

If the master decides to make the turn *in the bend,* i.e., away from the point, B (Fig. 10.6), the question arises when to turn. If it is started too late, the ship may ground on the bank *in the bend.* If he starts too early, there is a grave danger that the bank suction on one quarter added to the force of the current on the other may give the ship a rank sheer. The bank cushion under the bow will increase the sheer. If the bow should enter the eddies under the point, the ship may pivot and eventually ground on both sides of the channel at the same time.

Perhaps the safest way to turn with a following current is to approach the turn on a course a little to the bend side of the middle of the channel (Fig. 10.6), C. The eddies under the point and the increased current *in the bend* can be avoided, and the force of the current against the quarter can be used to assist the turn.

Two ships should not attempt to pass in a narrow channel in a bend. The ship which has a head current should stop and wait for the other to clear the bend.

10.18. Orders to the Wheel (Under All Conditions). Orders to the wheel and to the engine room telegraph must be given firmly and distinctly and repeated by the steersman or engine order telegraph operator in the exact words given as a check to show that they are understood and are being obeyed. A standard phraseology should be used to ensure a uniform result for changes in course and speed. In giving many of the commands to the steersman, the first word gives the direction so that the wheel can be started immediately, and the second gives the amount of rudder to be used.

"Right (left) standard rudder!" Standard rudder is the amount used to turn with a certain tactical diameter.

"Right (left) full rudder!" This is used when it is desired to make as short a turn as possible. The number of degrees to use for full rudder is always greater than that used for standard rudder. As the full throw of the rudder is about 35 degrees to each side, full rudder is set a few degrees less in order to ensure that the rudder will not jam hard over against the stops.

"Right (left) 5 (10, etc.) degrees rudder!" This command is used when a more gradual turn is desired than would be the case if either standard or full rudder were used.

"Right (left) rudder!" This order starts the wheel over in the desired direction immediately and must be followed by other orders as an obscure situation develops. It should seldom be necessary to use this order.

With an experienced steersman all the foregoing orders may be followed by an order to steady on a certain compass course. The steersman will carry this

out without further orders and report when steadied on the new course. With an inexperienced steersman or when the new course cannot be determined beforehand, the following orders are used:

"Rudder amidships!" This further slows the swing and is a warning that the new course is being approached.

"Meet her!" This order requires opposite rudder to stop the swing.

"Steady!" or "Steady as you go!" These are given the steersman when it is desired to keep the ship on the heading she has at that instant.

The object of these orders is to steady the ship on the new course without letting her swing past it with consequent loss of position and unnecessary use of rudder. The exact times at which the various orders should be given for each ship must be determined by trial and experience. One valuable point to note is that a ship with heavy weights, such as turrets near the bow and stern, requires more rudder to start and is harder to stop due to the momentum acquired during the turn.

Certain other orders to the wheel are used on occasion.

"Shift the rudder!" This is an order to change from right to left rudder or vice versa. It is often used while going ahead and backing in restricted waters to assist in a turn.

"Right (left) handsomely!" This order is used for small rudder angles to make slight changes of course. It is rarely used today and probably is unfamiliar to most steersmen.

"Nothing to the right (left)!" This is given when the course to be made good is a shade of the course set, and all small variations in steering must be kept to the right (left) of the compass course. It is frequently used to avoid obstructions, buoys, or passing ships.

All orders to the steersman in regard to the course must refer to the compass by which he is steering at the time and must be in the form "Course, Zero, Zero, Five." The steersman is not concerned whether the course is true or magnetic and must never be required to apply compass corrections of any kind. The officer of the deck should check the compass course upon assuming a new course and frequently thereafter.

The steersman must repeat all orders exactly as given and must report when they have been carried out. When he is relieved, he must report the fact to the officer of the deck and report the course being steered.

10.19. Orders to the Engine Order Telegraphs (Annunciators). Orders to the engine order telegraphs are in three parts:

1. The first part designates the engine, as "Starboard (port) engine" or "All engines." This puts the annunciator man on the alert.
2. The second part of the command gives the direction in which the engine order telegraph is to be moved, as "Ahead" or "Back."
3. The third part of the command gives the speed at which the engine is to be moved.

Thus: "All engines ahead full"; "Port engine back two thirds"; "Starboard engine ahead standard!"

Every order to the engine order telegraphs must be repeated word for word by the operator. When the engine room has acknowledged the order by the repeat back system on the telegraph, and the shaft revolution indicators show the engines are in the process of carrying out the order, the operator should then report what the engine is doing. Thus, upon the order from the officer of the deck, "Starboard engine, back one third," the operator repeats, "Starboard engine, back one third, sir." At the same time he rings up "back one third" on the starboard engine order telegraph. When this is repeated back from the engine room on the engine order telegraph, he reports, "Starboard engine answers back one third, sir."

10.20. Man Overboard. If the experiment is tried of throwing over from the bow a light buoyant object, it will be found that by the time this object reaches the stern it will be clear of the ship by a considerable distance. The surface wash will throw it off from the side. A man falling overboard may feel this wash to a certain extent, but he sinks in the beginning below its influence. Moreover, his first instinct is to swim back toward the ship.

One or more, preferably more, life buoys should be thrown over at once. If a little presence of mind is exercised here, it is often possible to throw one of these very close to the man and if possible between the man and the ship. At the first alarm a number of men (previously instructed through drills, etc.) go aloft to try to keep the man in sight; and as quickly as possible a quartermaster follows them with a pair of good binoculars and a set of semaphore flags.

The ordinary life buoy is so small that often the man in the water cannot see it, and it is of little or no assistance to the lookouts who are trying to keep him in sight. This is a serious and often fatal defect. It is well to keep a number of these small life buoys about the deck to be thrown overboard on the instant by anyone who may be near them; but in addition there should be available packets of sea dye marker for daytime use and battery-operated water lights for nighttime. These latter are necessary to serve as markers not only for the man but to keep the spot in sight from the ship. At least 50 percent of all life buoys kept about the deck should be equipped with the battery-operated lights mentioned above. The sea dye markers should be kept handy to each life buoy.

One method of maneuvering to recover a man overboard is to go full speed astern as soon as the man is clear of the screw and to lower a boat as soon as speed has been reduced sufficiently. The boat pulls back in search of the man and is guided by signals from the lookouts aloft who have semaphore flags, provided they have succeeded in keeping the man in sight. Failing this the boat cannot go far wrong if it pulls back on a course opposite the original heading of the ship, for, although the ship in backing will probably throw

her head to one side, she will not usually gain a great amount of ground in that direction before coming to rest.

In most conditions of the sea, a boat may be lowered with reasonable safety from a ship at a speed of 4 knots. If the weather is moderate or the sea calm or from such a direction that there is no occasion for maneuvering to lower the boat, all this is simple enough. If conditions are such that turning wholly or partially is necessary, many officers put the rudder hard over, keep the engines turning ahead at the same or even greater speed than before, and describe a circle, thus coming back, with the ship to a point near that at which the man went over.

Observations upon turning circles of a large number of ships show that a ship turning with hard over rudder will pass within a short distance, rarely so much as the ship's length, from the point where the rudder was put over. No doubt the symmetry of the curve may be considerably modified by wind and sea, but not sufficiently to prevent a return to the area of the starting point. The time required for the full turn will vary with the length, the speed, the weather, and the maneuvering powers of the vessel, especially the turning circle, the time required to describe it, and how close the ship will come to a marker thrown over just before putting over the rudder.

If the conditions are such—due to lack of a proper marker, or to fog, or to any other cause—that difficulty is to be anticipated in finding the man, it is probably better to stop and send the boat back along the course opposite the original heading. This emphasizes the need for having a compass in the boat. In case of fog, the ship should avoid changing her position while the boat is away. The compass is thus a guide for finding the way back—assisted, of course, by sounding the whistle.

There can be no question that in weather too heavy to admit of lowering a boat the one method that can give hope of saving a man is to turn and attempt to pick him up with the ship. In using this method the use of cargo nets over the side, attended by strong swimmers wearing immersion suits and with safety lines attached, is of immeasurable value.

Motor whaleboats are kept ready at sea for instant hoisting out and use as lifeboats.

Special rules are laid down for cases of man overboard in formation. All officers concerned must be familiar with these. Generally speaking, they provide for the necessary maneuvers to keep clear of other ships while picking up the man and for signals notifying other ships of the situation.

There are several different methods which ships may use to pick up a man directly without lowering a boat:

Method No. 1. This involves the use of the Williamson Turn.

Put rudder over with full rudder toward the side from which man fell overboard (if known). When ship's head has changed 60 to 90 degrees (varies for type of ship), shift the rudder and turn to the reciprocal of the original course. Speed may be increased as appropriate. This method is relatively slow, and

in poor visibility there is always the chance of losing sight of the man. However, it is an excellent maneuver to ensure getting back on the original track if the exact time the man went overboard is unknown or doubtful. It is also recommended for use in low visibility, particularly at night.

Method No. 2. A single turn toward the side from which the man fell overboard is another method. Hold original course for one minute; then, using full rudder and maximum speed available, turn until ship is headed for man. This method is fast and should be used if man is in sight.

Method No. 3. A two-turn maneuver is somewhat simpler for an inexperienced shiphandler in that it ensures the ship coming back to the spot where the man should be. A 180-degree turn with full rudder is made toward the man. Ship is steadied on reciprocal of original course until man is about 30 degrees abaft the beam. Another 180-degree turn with full rudder is then made again toward the man. The ship is steadied on the original course and should then be headed for the man. This method is not so fast as Method No. 2.

It is recommended that ships fitted with a Dead Reckoning Tracer mark the trace at the time the man goes over. A course to steer back to this point on the chart can then be obtained.

A method becoming increasingly popular in the Navy for use at night is for the ship to turn immediately toward the side from which the man fell overboard and train a searchlight on the life ring that was thrown over. When the turn is completed and an estimate is made of where the man went over, a life raft is released and the light shifted to the raft. The ship then circles slowly, keeping the illuminated raft as a reference point for the man and searching for the man at the same time on both sides.

Handling Steamers in Heavy Weather

In the days of sail and in the early steam vessels, most of which also had after sails, the conventional way to handle a ship when the weather was too heavy for her to proceed on her course was to bring her head up until she had the sea on the bow and to hold her there with the rudder and sail, with little or no resultant headway. If she fell off—as from time to time she did—and started to gather way, the hard down helm and after sail would bring her promptly back to meet the sea. Thus she came up and fell off making some little way through the water, but none of it against the sea, and, in the main, drifting steadily to leeward. For such bluff-bowed ships, this was and is the ideal way of riding out a gale. But a modern steamer, whether a man-of-war, liner, or tramp, carries no sail and is commonly long and sharp. The propeller acts as a drag, tending to hold her stern-up to the sea, and this tendency is assisted by the excess of draft which such steamers usually have aft. To hold such a steamer bows on to the sea, she must be forced into it—not at great speed, perhaps, but sufficiently great to maintain steerageway. This can strain the ship severely and causes grave doubt as to the wisdom of such a method of

lying to. The opinion of late years is that a steamer should run slowly before a sea or lie to with the sea astern or on the quarter; and this view is supported both by theoretical considerations and by a convincing amount of practical experience.

10.21. The Approach of a Tropical Storm. When a master is forewarned of the approach of a tropical storm, his first thought must be the location of the center and the estimated track of the storm. The geographical position of his vessel with respect to the proximity of land or shoal water, and whether his vessel will be in the dangerous or navigable semicircle of the storm, must be determined at once.

He should make an early decision and use all necessary speed to gain the safest possible geographical location before the storm is upon him. Once the center of the storm is near him, he should then be free to reduce speed, to avoid damage to his vessel. It may then be desirable to proceed at dead slow engine speed, barely maintaining steerageway, or even lie to for several hours until the storm passes. It might be desirable and safe to maintain a fair speed downwind.

If a master is unable to gain a satisfactory position with respect to shoal water, with the winds he can expect in a tropical storm, he may be forced to oppose the winds with appreciable engine speed, accepting risk of damages, to avoid being pushed into shoal waters.

On the other hand, if arrival in the navigable semicircle of a tropical storm before the storm is upon him is his only concern, he should not force his vessel in any continued effort to do so, but should ride out the storm as best he can.

10.22. Controlling a Ship in Very Heavy Weather. The easiest position for a ship in a very heavy sea would be that which she would herself take if left at rest and free from the constraint of engines, helm, and sails. A ship, if left to herself in a seaway will usually fall off until she has the sea abaft the beam, the propeller acting as a drag and holding her stern-up. In this position she will roll deeply, but easily, and will drift to leeward, leaving a comparatively smooth wake on the weather beam and quarter, rolling deeply, but in most cases easily, and taking little or no water on board. If oil is used along the weather side and astern, the wake can be converted into an "oil-slick" and danger of seas breaking on board effectually prevented.

If a ship rolls dangerously, she may be kept away more from the wind and sea by using a drag over the stern, or by turning over the engines just fast enough to give her steerageway; for it seems to be established, as the result of experience, that a steamer may safely run with the sea aft or quartering, *provided she runs very slowly*. Clearly this is not "running" in the old sense of that term, according to which a vessel going before the sea was forced to her utmost speed with the idea of keeping ahead of the waves, which were expected to "poop" her if they overtook her. It is evident from the statements of a large number of shipmasters who have tried the experiment of slowing down or stopping when running before a heavy sea, that this maneuver, so far

from resulting in the disaster which many seamen would expect from it, had an extraordinary effect in easing the ship and keeping her dry.

The explanation of this seems to be that a ship running at high speed through the water draws a wave after her which follows under her counter and rolls along toward the waist on either side, tending continually to curl over and break on board. This wave is reduced to insignificant proportions in running dead slow.

10.23. Roll and Pitch. Another point which enters into the behavior of a vessel going before the sea is that as she rolls and pitches she buries first one bow and then the other, increasing the pressure on the bow so buried. If she is being driven through the water, her head will be forced off, first to one side and then to the other, causing her to yaw badly with a continual tendency to broach to. This cannot be met by the rudder, because, at the very time the bow is buried, the stern is lifted more or less out of the water, and the rudder loses, for the moment, its steering power. As the stern is lifted, there also comes a racing of the propeller which is in itself a serious danger at high speed. There seems no question that the dangers connected with running, so far from being increased, are greatly reduced if not altogether removed, by slowing or stopping.

It will of course be understood that in this matter, as in all others connected with seamanship, due regard must be had for the peculiarities of the individual ship and that the maneuver which is safest for a majority of ships may be dangerous for certain ones. Thus a ship whose cargo may shift should not be allowed to roll excessively; nor should a warship whose heavy guns or missiles are carried high above the center of gravity. On whatever course the vessel may be kept, this rule may be regarded as of universal application; that, other things being equal, *the lower the speed at which she is run, the easier she will ride.*

10.24. Relation Between Ship and Waves. Attention is invited here to an important relation, not always recognized, between a ship and the waves in which she floats. For every ship (in a given condition as to trim, etc.) there is a perfectly definite "rolling period"; a period, that is to say, in which she will make a complete roll, *without regard to whether she is rolling 10 degrees or 40.* So, also, in the case of a seaway, there is usually a fairly regular interval of time between wave crests passing a given point. If the point is a ship in motion, her motion may increase or decrease the interval between the waves so far as she herself is concerned; but this will not change the *regularity* of the interval. If it happens that this interval coincides with that required for the ship to complete a roll, each wave as it passes her will add its rolling impulse to the accumulated effect of those which have preceded it, and the ship will roll more and more deeply until she reaches *the maximum roll of which she is capable.* She will not capsize (if properly designed and is undamaged) because there are forces at work to resist the rolling, and these increase as the depth of roll increases, until the rolling forces and the resisting forces balance. But she will continue to roll to the maximum limit until something is done to

break up the synchronism between her period and that of the sea. This can be accomplished, *provided the ship has headway*, by changing the course or the speed, thus changing, not the real, but the apparent, period of the waves. By running more nearly into the sea—meeting the waves—the apparent period is shortened; by running more nearly before it, the period is lengthened; but in either case it is *changed* and will no longer agree with the rolling period of the ship. The same effect is produced by a change of speed. If, therefore, it is judged from the violence of the rolling on a given course that the period of the waves is coinciding with that of the ship, the course or speed or both should be changed.

A ship making high speed in the direction of a heavy sea or swell may take a sheer and roll very severely. This has happened to destroyers during high speed trials with men being washed overboard and lost, as the ship, without warning, took a maximum roll. A moderate following sea, accompanied by a less obvious swell from a slightly different direction can occasionally coincide or harmonize, producing a very large sea astern which, if the steerman is not alert and experienced, can produce the sudden roll mentioned above. Vigilance by the conning officer and good steering are the obvious preventions in addition, of course, to keeping men off the weather decks.

The length of the ship, as compared with that of the waves, is also a very important factor in the behavior of the ship, especially when she is running more or less with the waves or meeting them. It often happens that a small ship, in a long sea, will be perfectly comfortable where a larger and longer one makes very bad weather. The small craft climbs up and slides down the waves, accommodating herself to their slopes, and pitching only as the slope changes; but the longer craft, partially spanning the crests and the hollows of the waves alternately, one end being poised on the crest of one wave while the other end is buried in the adjoining one, may be making very heavy weather. A few years ago a large aircraft carrier in the Philippines was badly battered by a typhoon, but a destroyer escort, which passed through the same gale at very nearly the same place, was perfectly comfortable.

10.25. Bringing a Ship Bows-On. If, when a steamer is before the sea or in the trough, it is decided to bring her up to it, bows-on, she should first be slowed until she has barely steerage way, and should then be brought up as gradually as possible. To put the wheel over with considerable speed on and bring her up with a rush—slapping the sea in the face, as it were—would result in serious damage, if not in foundering. After getting her up to the sea bows-on, the greatest watchfulness is required, first, to avoid falling off into the trough of the sea, as she will try to do the moment she loses way; and second, to avoid driving into the heavy, breaking seas, which will threaten her now and again. There is reason to believe that many of the phenomenal "tidal waves" reported as having suddenly overwhelmed steamers in mid-ocean have been simply the exceptionally heavy waves which build up from time to time in any long-continued gale; and that their destructive power was due to the fact that the

vessels were driven into them instead of being allowed to drift before them and ride over them unresistingly. An officer should always be kept at the engine-room telegraphs, in lying to bows-on, and an engineer standing by below, to obey his signals instantly. So long as she heads up to it, the more slowly she turns over, the better. If a heavy sea is seen bearing down upon her, she should be stopped altogether. If she falls off, it will be necessary to increase the speed a little to bring her up, but she must be slowed again as soon as possible.

10.26. Using a Sea Anchor. With small ships, and especially with yachts, a sea anchor has been used with good results. Such a ship, riding to leeward of a sea anchor of fair size with an oil bag hauled out to a block on the hawser well clear of the stem, and drifting slowly astern, will ride out almost any gale with safety and comfort. Indeed, as has been said above, this is the ideal position, in very bad weather, for any vessel which can be made to take and keep it. It is doubtful if a large steamer could be made to do this without the use of an anchor too unwieldly to be handled conveniently in a heavy gale.

10.27. Practical Sea Anchors. In cases where a light drag is needed and no sea anchor is available, a boat may be used, with a hawser made fast to a span from the bow and stern ring bolts, and to a belly band amidships. A long spar (or a number of spars lashed together) may be used, also slung by a span. If a heavy awning can be added to such an improvised anchor, it will help to break the sea.

There are cases recorded of vessels having been kept head to sea by paying out their chain cables, unbent from the anchors. Where the water is shallow enough for the chains to drag on the bottom, they are especially helpful. A good-sized manila hawser, paid out *on the bight*, both ends being kept on board, makes a very convenient drag—perhaps the most convenient that could be devised. With both ends leading in through the stern chocks, it would be extremely helpful for holding her stern-on, and with one end at the stern and the other at some point near the beam, she could be held with the sea on the quarter. A block on the hawser would admit of reeving a line for hauling oil bags out and in.

In twin-screw ships, the propellers have not as much drag as with single screws, and such ships can sometimes be held up the sea without being driven into it dangerously, by turning over the lee screw very slowly. This is often the best way to lay a twin-screw ship to, although there is nothing in the nature of the case to prevent such a ship from riding easily with the sea astern or quartering.

10.28. The Calming Effect of Oil. The effect of oil in calming a rough sea has been known from the earliest times. The action of the oil is not only to prevent the breaking of waves, but to a considerable extent also to prevent them from forming. Its effect, when used on an angry sea, is described by all who have tried it as magical. Even in a surf, while it cannot altogether prevent the waves from breaking as they are driven in upon the shoals, it

greatly reduces their violence and will often enable a boat to land when otherwise it would be out of the question.

Almost any kind of oil will give good results, but some kinds are very much better than others. Animal and vegetable oils are best; for example, sperm, porpoise, linseed, olive, and cotton seed; and fairly thick and heavy oils are better than lighter ones. Oil of turpentine is probably the best of all. Mineral oils are much less effective; however, a very thick sticky oil, or one that tends to thicken or congeal in cold weather, may be improved by thinning with petroleum. Soapsuds has a remarkable effect in preventing the formation of waves, but it does not keep them from breaking when formed.

Any method will answer for dispersing the oil which produces a slow and steady flow. A convenient way is to fill the closet bowls with oakum and oil, or to place a slightly opened can where it will give a slow drip into the bowls and out through the waste-pipes. A still simpler way and one frequently used is to fill a canvas bag, 1 to 2 feet square, with oakum and oil, and punch a number of holes through the canvas with a sail needle. Such a bag may be hung over the side at any point where it is found to give the best result. If there is danger of its being thrown back on board by the sea, its lanyard may be led through an eyebolt or a shackle in the side. If for any reason, a very rapid flow is wanted, a hose may be led through a scupper or over the rail, and the oil poured into it through a funnel; or, in a sudden emergency, the oil may be thrown or pumped over the side. The quantity used need not exceed a few gallons—4 or 5 at most—even for a large ship riding out a prolonged gale.

It should be noted that the rate at which the oil spreads is slow in comparison with the speed even of a vessel drifting. Thus a vessel lying with engines stopped can make a "slick" to windward but not to leeward—except, perhaps, very close alongside—because she drifts faster than the oil can spread. So, in running, a vessel can leave a slick astern and to some extent on either hand, but can do nothing to calm the waves ahead of her. She can, therefore, avail herself of the benefits of oil if she is running more or less before the sea, but not at all if steaming into it.

10.29. Summary. We may sum up the various methods of handling a ship in heavy weather with the statement that the ship will usually be safest and most comfortable when stern-to, or nearly stern-to, to the sea, and *drifting before it.*

If, by the use of sails, a drag, or any other means, she can be held bows-on, *while being still allowed to drift,* this is probably the best way to lay her to; but if she cannot be held up without being forced into the sea, it will be because of the natural drag of the stern and propeller, and in this case advantage should be taken of this drag to hold her more or less directly stern-on, letting her drift in this way.

Even if the position she takes up in drifting is nearly in the trough of the sea, it will usually be found that she is easier in this position than in any other;

however, the use of oil, as described above, is especially important in such cases.

If the position which she takes in drifting proves to be one in which she rolls dangerously, then she may run fast enough to steer, *but no faster,* and so keep the course which is found most comfortable.

One final word of caution. The effect of "free surface" water in bilges and compartments is particularly important during heavy weather when a ship's stability is severely tested. Pumps must be kept operable to remove water; electrical switchboards must be kept dry. This points up to the need for making watertight closures well in advance of the onset of the worst part of the gale. To minimize free surface effect (see Chapter 3) it is advisable, particularly when bad weather is expected, to keep all tanks containing liquid either full or empty.

11

Docking and Mooring—Handling Alongside

Mooring Lines

The lines used to secure the ship to a wharf, pier, or another ship are called *mooring lines.* Five-inch manila or smaller nylon is used for mooring lines in destroyers or smaller vessels. Larger ships may use 8- or even 10-inch lines. The manila lines may be reinforced or replaced by heavier lines or wire hawsers when the ship is finally securing alongside. Nylon lines are common now for all types of ships.

The mooring line which runs through the bull nose or chock near the eyes of the ship is called the *bowline.* The corresponding line aft is the *stern line.* These lines should lead well up the dock to reduce the fore-and-aft motion of the ship. Other mooring lines are either *breast lines* or *spring lines.* They are called bow, waist, or quarter breasts and springs, depending on the part of the ship from which they are run. Breast lines are run at right angles to the keel and prevent a ship from moving away from the pier.

Spring lines leading forward away from the ship at an angle with the keel are *forward* (*bow, waist* or *quarter*) *springs.* Springs leading forward or aft prevent a vessel from moving aft or forward, respectively.

If a ship moves ahead or astern with lines out, a breast may become a spring, and spring lines may change their leads. In the U.S. Navy, to prevent confusion and to add to the efficiency of line handling, lines are numbered from forward aft, according to the position where they are secured aboard ship. A ship may use fewer or more lines as necessary in which case the numbers are changed accordingly. The names are used after the ship is secured and the use and lead of each line becomes definite. Figure 11.1 shows the names and numbers for seven mooring lines.

Lines can be of the greatest assistance in making or clearing a pier. Prior to a ship coming alongside, the required lines with eye splices or bowlines in the ends should be led through the chocks up and over the lifelines. Heaving lines that have been successfully passed should be made fast near the splice and not at the end of the bight where they will become jammed when the eye is placed over the bollard. Heaving lines should be passed as soon as possible;

then the heavy lines, the bights of which are necessarily hard to handle, may be run later when the vessel is farther up the pier and nearer her berth.

As a large ship works her way up the pier or into the slip, the lines should be *fleeted* up the pier in short steps, thus keeping them in position for use.

If two bights or eye splices are to be placed over the same bollard, the second one must be led up and through the eye of the first and then placed over the bollard. This makes it possible for either to be cast off independently of the other. This is called *dipping the eye.*

The ship in (a), Fig. 11.2, is lying off a pier with a bow breast line secured to a bollard. If the line is led to a winch and a strain put on it, the bow will

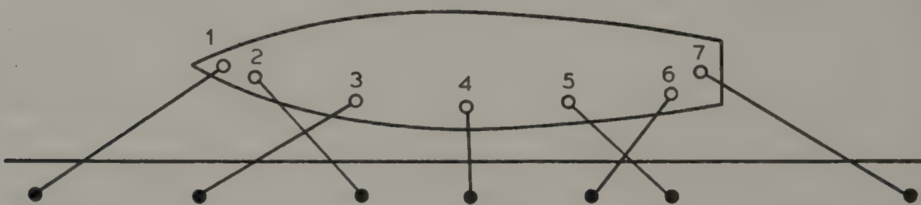


FIG. 11.1 (1) BOWLINE (2) AFTER BOW SPRING (3) FORWARD BOW SPRING (4) WAIST BREAST (5) AFTER QUARTER SPRING (6) FORWARD QUARTER SPRING (7) STERN LINE

swing toward the pier, and the stern will move out. It should be noted, however, that the stern does not go out as much as the bow comes in. Because the ship is not held rigidly at the pivoting point, the mass as a whole will respond to the force acting on the bow, and the resultant motion will be like that shown in the figure.

If, in the above case, the stern is held by a line to the pier as shown in (b), the pivot is transferred to the stern, and the whole ship moves toward the dock. This requires much greater effort than to turn the ship near her natural pivoting point as in (a).

If the bow and quarter breasts are hove in at the same time, the ship will be breasted in bodily but at greater expenditure of work than in the preceding cases.

If the ship has way on, either ahead or astern, her momentum enters into the problem of her behavior. In Fig. 11.2(c), the steamer is moving forward parallel to the face of the pier (with engines stopped and rudder amidships). The after quarter spring "A K" is taut. The motion of the ship will be that resulting from her momentum along the original course and the tension along A K. The tension on A K may be resolved into two components. One retards the ship along the line of her original course and thus directly opposes the momentum, and the other moves her toward the pier. The stern will swing in and the bow out. It is important to note, however, that the momentum which is concentrated at the center of gravity forward of the pivot (A) opposes the turning and tends to keep the ship parallel. Thus, as a matter of fact, the ship does not turn much but comes in nearly parallel to the pier as shown in Fig. 11.2(d).

The vessel in Figs. 11.2(c) and (d) could go ahead on her engine(s) and put her rudder left to throw her head in. Since the steering effect of the rudder is due to the discharge current against the rudder and since the stern cannot move to starboard because it is held by the spring, left rudder can have

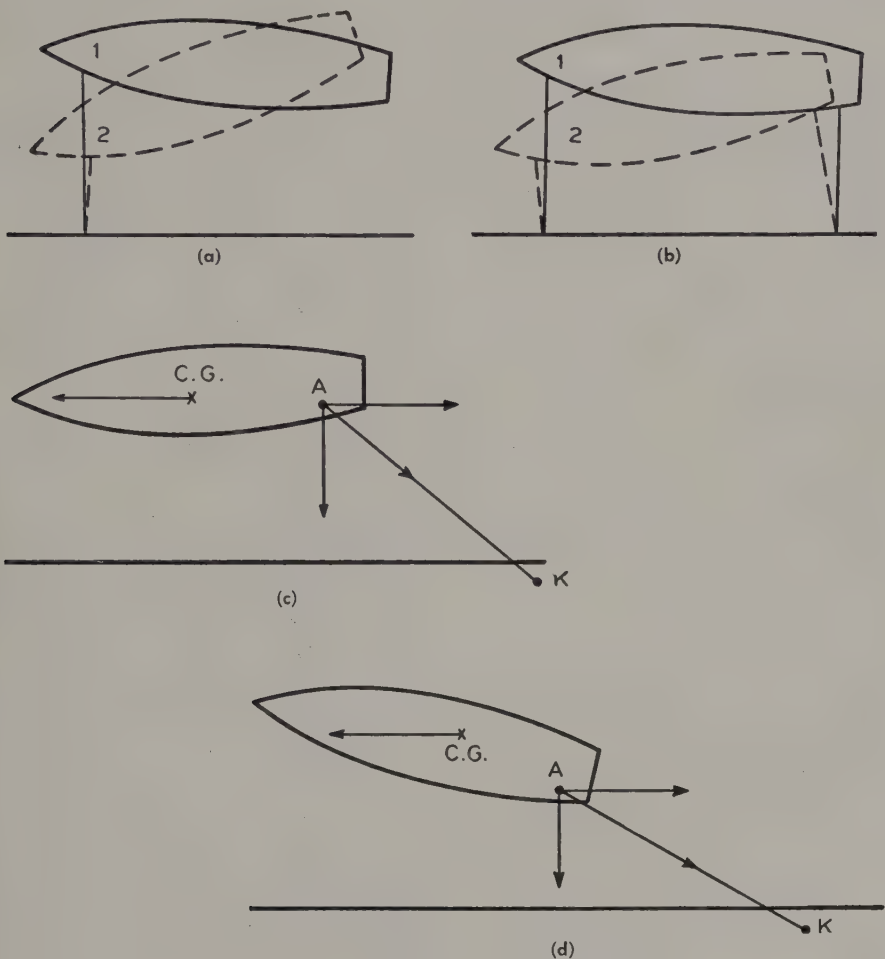


FIG. 11.2 HANDLING SHIP AROUND A PIER

comparatively little turning effect. Right rudder, on the other hand, will help to throw the stern in.

If in Fig. 11.2(a) the rudder is put left, it will throw the stern out and increase the rapidity with which the bow turns in. If put right, it will oppose the turning but not enough to overcome it.

In any case, if the line is made fast at the ship's natural pivoting point, and the engine(s) are turned over ahead or astern, the ship will spring in bodily.

Her heading can be controlled by putting the rudder over, which throws the stern to either side, as desired. The ship swings under the influence of the rudder while coming bodily in on the spring, and it is often possible to come alongside quickly and smartly by using this line only.

Orders to the Men at the Lines

COMMAND	MEANING
Slack (Slack Off) the Bowline (Number One):	Pay out the line specified, allowing it to form an easy bight.
Take a Strain on One (or Number One):	Put number one line under tension.
Take in the Slack on Three (or Number Three):	Heave in on number three line but do not take a strain.
Ease Three:	Pay out number three enough to remove most of the tension.
Avast Heaving	Stop heaving (taking in)
Check Three:	Hold number three line but not to the breaking point, letting the line slip as necessary.
Hold Two:	Take enough turns so that the line will not give.
Double Up and Secure:	Run additional lines or bights of lines as needed to make the mooring secure.
Single Up:	Take in all lines but a single standing part to each station, preparatory to getting underway.
Stand by Your Lines:	Man the lines, ready to cast off or moor.
Let Go:	A command to slack off smartly to permit those tending the mooring lines on the pier or other ship to cast off.
Take in One (or Number One):	Retrieve line number one after it has been cast off. When used by the conning officer it means to slack one, cast it off, and then pull it back aboard. When used by the officers in charge on the forecastle it is preceded by the commands "slack one" and "cast off one" and means merely to retrieve line number one and bring it back on deck.

COMMAND	MEANING
Cast Off:	A command *to those tending the mooring lines on the pier or on another ship* to disengage or throw off the lines from over the bollards or cleats.

In securing alongside a dock, wharf, or pier, special attention must be paid to the state and range of the tide. When securing at high water, enough slack must be left in the lines to ensure that at low tide they will not part, carry away bollards, or in extreme cases list the ship to a dangerous degree or even capsize small vessels.

11.1. Making Landings. The names *dock, pier, and wharf* are used almost interchangeably. These are all structures connected to the shore with enough water up to them for vessels to come in or alongside. A pier is built at right angles to the shore; a wharf is parallel. Both are sometimes called docks, although strictly speaking a dock is a structure used for drydocking a vessel. The space between neighboring piers is called a *slip.*

Wharves and piers may be built on piles which allow a fairly free flow of water under them and in the slips between them. Their underwater construction may be solid, in which case there will be no current inside the slips, but eddies of various sorts may be found. Warehouses or other buildings may be built on them which may result in varying the effect of the wind on the upperworks of a vessel.

Wind and current at right angles to a pier are always more dangerous than when they are blowing or running respectively along its face. In coming alongside the conditions of wind and current existing should be observed carefully, and they should be used to assist when possible. Several cases of going alongside under different conditions of wind and current will be discussed.

11.2. Going Alongside, No Set On or Off the Pier (Single-Screw Vessel). A single-screw (right-handed) vessel can make a landing to port with little difficulty under these conditions. The ship should be headed for a point a short distance outboard of the place where the bridge will be when the ship is secured. The course of the approach should be at an angle of 10 or 15 degrees with the face of the pier. Slow speed should be used, and the engines should be stopped when there is sufficient headway to reach the berth. Enough headway to steer should be retained when the ship is almost abreast of her berth; the engine can be backed to stop the ship and to swing her stern to port and then parallel the pier. The ship can then be breasted in by the mooring lines and winches. If a single-screw ship must go alongside to starboard, the angle of approach should be about 10 degrees. The speed should be less than that used for a port landing but still enough to keep the ability to steer. The point for which the ship should be headed during the approach should be the final position of the bridge when secured.

The port anchor may be dropped at short stay during the early part of the approach. The anchor is then dragged over the ground. The anchor will add to the steering ability, reduce the speed of the ship, and give the master better control of the bow and the stern when the final landing is being made. The difficulty at that time is that reversing the engine will force the stern away from the pier and the bow toward the pier when a *close* landing is contemplated.

The engines should be stopped later than would be done with a port landing. The dragging anchor will enable the ship to be stopped without backing with much power or for a long time. The anchor will probably enable the master to lay the ship alongside her berth without backing at all or perhaps with just a touch astern.

Every effort should be made to get a stern line out as soon as possible so that this line can be held when the engine is backed and the stern prevented from swinging away from the pier.

11.3. Going Alongside Port Side to Being Set On to the Pier. The point for which the ship should be headed at the start of the approach should be farther away from the pier than the one used with no set. The angle of approach should be 20 to 30 degrees, and the speed of approach should be higher than above without attempting a high-speed landing. The amount of set ought to be watched constantly. If it is apparent that the set is more than anticipated and that, if the ship continues, she will strike the pier, there are four choices:

1. Head farther away from the pier.
2. Back clear and try again.
3. Stop with the ship parallel to the pier while there is still some open water between the ship and the pier.
4. Proceed at greater speed in order to reduce the time during which the ship is subject to the wind and current.

The conditions near the berth, the proximity of the berth, and the course will determine what action is advisable. If there are ships alongside of the pier ahead and astern of the allotted berth, it is probably wise to head up or back clear and try again. If there is a clear space astern of the berth, it may be possible to make a landing short of the correct berth and, once alongside, move up to the berth. There is always the fourth choice in which case the discharge current from the backing screw may cushion the impact somewhat.

11.4. Going Alongside, Starboard Side To—Set On to the Pier. If a single-screw ship attempts a starboard landing with a set on to the pier and finds that she is too close, the four choices of action are still available but number two should be changed to: stop with the ship heading slightly away from the pier. In this position she can back, and, in so doing, the stern will swing away from the pier. The ship will parallel the pier, lose her headway,

and the discharge current will cushion the impact. The first choice, to head up, is not as satisfactory as before because the original approach course should make a smaller angle of about 10 degrees with the face of the pier. There is not as great an angle through which to head up, as was available in a port landing.

11.5. Going Alongside a Pier—Being Set Off. Should it be seen that the vessel is being set off the pier, the ship's head can be pointed well up into the pier and the approach made with more speed. The bow lines are gotten out, and, when close to the pier, the rudder is put away from the pier. For a single-screw vessel, port side to, the landing is easily made by backing down on the screw. For a single-screw vessel making a pier to starboard, the approach should be made by snubbing the port anchor as previously described. In addition to snubbing the port anchor, a starboard quarter breast can be used to hold in the stern as the ship forges slowly ahead on it. In a twin-screw vessel, the outboard engine is backed full.

11.6. Going Alongside—Current from Ahead. When a current is running parallel to a wharf, the ship should be headed into the current and then brought alongside. Slack water is the most favorable condition; yet the current, if not too great, can be used and the berthing accomplished without trouble, except in the case of the largest vessels. With current from ahead, a vessel can use more speed through the water without increasing its speed relative to the wharf; therefore, the ship will have better rudder control.

The ship, making little headway along the face of the wharf, is brought in fairly close and parallel. The vessel must not be canted in because she might come in too fast and cause damage. A forward bow spring is sent well ahead and up the wharf.

When in position relative to the pier, all forward motion relative thereto is stopped, and the vessel is slowly dropped back on the spring. The amount of tension on this spring determines the rapidity with which the ship drifts in to the wharf. The rudder may be used to swing the stern.

Should the current be very strong, the ship should go a little way above the wharf and drop the outboard anchor. A forward bow spring should be run ashore. By veering chain and holding the spring, the ship will swing slowly in toward the wharf. By using the rudder and adjusting the strain on the anchor chain, perfect control can be maintained. When alongside, a bow breast and forward quarter spring are got out as soon as possible.

11.7. Going Alongside—Current from Astern. Making a pier or wharf with a fair current is difficult and should be avoided when possible. If there is swinging room and if other reasons do not forbid, much time and fuel will be saved and danger avoided by dropping an anchor, swinging with the tide, and making the pier as previously described with the current from ahead. If this is not practicable, tugs should be used if available. If a tug is not available, the approach should be made as slowly as possible and as near to the pier as

is safe. When about in position, the bow is canted out a few degrees from the pier. An after quarter spring is got out as soon as possible and the engines backed to keep from parting the line. Backing on the inboard engine of a twin-screw ship forces more water between the pier and the ship, thus cushioning her as she comes in. Care must be taken to prevent the stern from swinging away from the pier. The use of after spring lines and stern lines with the outboard engine backing will prevent this movement.

11.8. Clearing a Pier—No Wind and No Current. Clearing a pier is less difficult than making a pier. The first step is to slack all lines carefully and observe the effect. If the ship does not drift out, it will be necessary to force the stern away from the pier.

In a single-screw ship with the starboard side to the pier, the engine is backed. This swings the stern rapidly to port. If the bow is forced into the pier, right rudder is used to clear it as the ship goes astern. When the stern is about 50 feet out, the bow will be pointed in toward the pier. A quarter breast which becomes a spring as the ship continues to go slowly astern is now held. This action will bring the bow out. When pointed fair, the ship casts off and goes out ahead.

If the port side is to the pier, an after bow spring is used as the ship goes ahead slowly on it. Left rudder throws the stern well out. The ship is cast off and backed down slowly with right full rudder until clear. As the stern will gradually turn in toward the pier, it will be necessary to stop when parallel to the pier and several beams' width out from it. The vessel now goes ahead with right rudder, and the bow falls off as required.

A twin-screw vessel can shove off from a pier easiest by holding the after bow spring and slacking off all other lines. The outboard engine is turned over, slow ahead, until the inboard propeller is clear of the pier. Fenders can be used as necessary on the bow. Once the inboard propeller is free, let go all lines, and back both engines slow. The discharge current from the inboard propeller will breast the vessel out, particularly if the pier is a solid one. The officer conning should glance aft to note any tendency of his ship to start swinging either way. He should use the engines for steering until sufficient sternway is reached when the rudder can be used. The distance between the pier and the bow should be noted and the rate of turn regulated to prevent touching. The inboard screw discharge current when it reaches the bow tends to keep the bow off.

11.9. Clearing a Pier—Being Set On. This is a difficult situation. To go out ahead without the use of tugs or an outlying anchor is risky. The ship must be taken out astern. A single-screw ship with her starboard side to the pier should go ahead on an after bow spring, and when the stern is well out, cast off and go astern full. If she is port side to, it is advisable to wait for a change in conditions.

A twin-screw vessel should first go ahead on the outboard engine, holding the after bow spring. This will throw the stern out against the set. Then the

ship should cast off the spring and back immediately on both engines. The wash of the inboard engine will tend to keep her off, and the speed of the inboard engine can be varied to keep the bow clear.

11.10. Clearing a Pier—Being Set Off. If the ship tends to drift out when all lines are slacked, the clearing of the pier is very simple. Continued slacking away on the lines will ease the ship off the pier. All lines are then cast off and the ship can proceed.

11.11. Clearing the Wharf—Current from Ahead. Ease off on all lines except the forward quarter spring. The stern will come in and the bow will go out where it will catch more of the current. While going ahead very slowly to keep the stern and the propellers away from the wharf, the bow will continue to swing. When far enough out, the ship may cast off all lines and proceed.

Should the stern not be clear to go ahead on the engines, a bow breast should be kept under a light strain, and, when the ship is headed correctly, the breast should be checked while slacking the quarter spring. The stern will swing out and clear, and all lines can then be cast off and the engines put ahead. To use the bow breast in this manner, the bow must be farther out than the stern; otherwise the ship will come back alongside.

Should the wind prevent the bow from falling off, it will be necessary to go out astern as previously described for a ship being set on to the wharf.

11.12. Clearing a Wharf—Current from Astern. Holding an after bow spring and easing out on a quarter breast will let the stern swing outward. When pointed correctly all lines are cast off, and the ship goes out astern.

11.13. Working into a Slip. The best time for entering a slip is when the water is slack. The procedure is the same as in making a pier. In entering, an anchor under the forefoot for snubbing is of great assistance, since it gives greater steering control.

Should there be a good current running, the docking should be done with tugs; but if they are not available, the ship can make a landing on the end of the pier, heading into the current.

The ship is then warped into the slip. The springs for this purpose should be as short as possible to reduce the radius of the swing and should be as nearly perpendicular to the keel lines as practicable to produce the best springing effect. To protect the ship's side and the pier, a camel or suitable fenders are placed at the knuckle of the pier where the pressure is localized. The camel will distribute this pressure over many of the ship's frames, thereby preventing the crushing of them. The ship goes slowly ahead until the knuckle of the pier is amidships. Then the after bow spring is held and the rudder is thrown hard over toward the pier, aiding in the turn. After entering the slip, if being set off, the lines should be got out and walked up the pier in short steps and used as necessary to hold the ship in. If being set on, lines are run to the opposite side of the slip.

When backing into the slip the same principles of using the springs apply. The lines, especially the bow breasts, must be very strong, and good seaman-

ship dictates that more than one be run. The additional ones are preventers and are used as alternates in the shifting of the lines for better leads. The vessel is dropped back until the knuckle of the pier is amidships, and with the quarter spring held the bow breast is eased. When the ship is pointed correctly, the engine is backed slowly. Deck winches are a help and almost a necessity in the case of a single-screw ship backing to starboard.

The most difficult problem is making a landing on the upstream side of a slip, with the wind and current from the same direction and at right angles to the pier, its underwater structure solid, and a large warehouse built upon it. Under these conditions entering the slip at slow speed will invariably result in the ship's stern being swept across to the other side of the slip before it can be controlled, with almost certain damage to the ship, the pier, or other shipping. Such a landing is sometimes possible with a high-powered vessel by entering the slip at a high enough speed so that the stern will be out of the effect of wind and current before it can be swept across the slip and then backing full to kill the headway. Such a maneuver requires expert judgment as to the instant of backing and perfect coordination with the engine room in order to avoid ramming the head of the slip.

11.14. Mooring to a Buoy. The ship should approach slowly with the current from ahead, and the buoy should be kept on a constant bearing. The buoy should be picked up on the lee bow if there is any wind so that the bow will drift toward it rather than away. It may be wiser to pick it up on the starboard bow in the case of a single-screw ship because of the tendency of her bow to drift to starboard when the engine is backed.

Most large ships moor by shackling the end of the chain, unbent from an anchor, to the ring of the buoy. Small ships may pass the end of the chain through the ring, haul it in, secure it on deck, and ride to the bight, but this is not recommended because the chain can be damaged where it is passed through the ring. In case the mooring is made habitually, a heavy wire mooring pendant with an eye and shackle on the end may be made up. In any case a hook rope is first passed to hold the bow in position while the moor is being made, and a man is placed on the buoy to handle lines and shackle up. Under favorable conditions, the man can be lowered over the bow and the hook rope passed down to him, but it is better to send him to the buoy in a boat. The same boat can carry the hook rope and a messenger fastened to the end of the chain. The hook rope is secured first. Care should be taken not to put too much strain on it or the buoy may be capsized and the man working on it thrown into the water. Next the messenger is run from underneath through the ring and brought back on deck to the capstan. The messenger is used to haul the end of the chain down to or through the ring. The shackle and pin, if used, can be taken in the boat or preferably lowered from the bow with lines, thus making it easier for the man on the buoy to handle them.

Some destroyers send out the bight of a heaving line in a boat. The bight has been cut and a ring and snaphook inserted. The man in the boat reeves

one end of the heaving line through the ring on the buoy and snaps the ends together. The mooring party on the forecastle hauls the heaving line through the ring rapidly. A heavier messenger follows as the ship approaches the buoy. The anchor has been secured and enough chain roused up to allow the end to be reeved through the bull nose and to hang down to the water. As the ship gets closer to the buoy, the messenger which is made fast to the end of the chain is hove in. The chain reeves up through the ring on the buoy and is hove up on deck and secured. Such a mooring can be made in 1 to 2 minutes. It is important in all moorings to bring the ship up to the buoy and not attempt to pull the buoy to the ship.

Large ships, such as cruisers, with heavy chains usually moor close to the buoy with a wire. The anchor chain is then shackled to the wire and slides down the wire where it is made fast to the ring on the buoy.

A buoy can be picked up with a fair tide under some circumstances. It will require skillful shiphandling and speedy work by the man on the buoy unless the ship has twin rudders. When the vessel swings, it may put a severe strain on the moorings. In some cases, time will be saved if it is possible to drop an anchor, swing, and pick up the buoy with the current from ahead.

11.15. Slipping a Mooring. A strong manila line or flexible wire is run through the buoy ring and back on deck to use as a slip rope. A strain is taken on it, and the chain is unshackled. Should the ship be riding to a bight of the chain, an easing-out line is used to ease the chain through the ring while the chain is hauled in. The ship is now riding to the slip rope, and unmooring is completed by letting the end of the slip rope go and reeving it through the buoy ring.

11.16. Mooring to Buoys, Bow and Stern. It is sometimes necessary to moor bow and stern to two mooring buoys in order to avoid any swing in a restricted space. When possible, the approach should be made against the current and on the side from which any wind or current present will tend to set the ship down on the line of buoys. The bow is moored to the upstream buoy in the usual manner. Meanwhile another boat should be used to carry a line to the second buoy to hold the ship's stern from swinging off. This line should be no heavier than necessary so that it can be handled easily, and care must be taken always to keep it way from the screws. The end of a wire of sufficient strength may then be carried out and shackled to the buoy ring. The first line may be taken in or kept as a preventer and for use in unmooring. The final moor should be taut in order to prevent the vessel from ranging ahead or astern. This may be ensured by heaving in on the stern line with an after winch or by veering on the buoy chain, taking in the required amount of stern line, and then heaving taut on the chain.

11.17. Winding Ship. It is seldom necessary to wind ship at a pier. When it must be done, the most satisfactory method is by the use of tugs, especially in the case of large ships. Tugs give better control and assist the engines to turn the ship. With a small ship or when no tugs are available, it is quite pos-

sible to wind ship by the use of the engines or by taking advantage of the current.

It is safer to pivot on the bow and thus avoid possible damage to the rudder and screws against the pier. An after bow spring should always be held on the stern lines slacked or let go. With a current from astern the stern will usually start out by itself. With a single-screw ship, starboard side to, backing down slowly will usually start the stern out. If port side to, going ahead dead slow on the after bow spring will have the same effect. With a twin-screw ship, backing the inboard screw or going ahead on the outboard one or a combination of the two should start the stern out. The swing is made on the after bow spring, but a forward bow spring on the other bow should be led from well aft

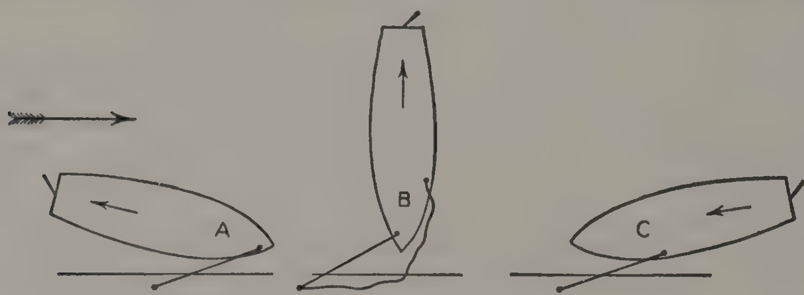


FIG. 11.3 WINDING SHIP

to assist in controlling the swing and to take the strain after the swing is past 90 degrees, as shown in (a) and (b) of Fig. 11.3. The bow is kept clear of the pier by backing a little as needed. Should a strong current be running, a long after breast may be used to slow down the first part of the swing. During the latter part of the swing the engines may be used to slow the swing and to prevent the ship from slamming into the pier. After the winding is completed, the ship can be spotted in position with the engines or by hauling her ahead of the vessel's original position.

11.18. Going Alongside Another Vessel. In going alongside another ship at anchor or at a mooring buoy, the same general rules apply as for going alongside a pier. The anchored vessel may be riding to the current. Her stern should be watched carefully during the approach, as it may yaw, and allowance must be made for the effect of the wind. On the windward side, the ship coming alongside may expect to drift down fast on the anchored vessel. On the leeward side, a close approach must be made or the landing may be missed.

There is a double possibility of damage when going alongside another ship. Projections, such as bridge wings and sponsons, must be watched carefully to make sure they do not foul. There should be no headway or sternboard on the vessel coming alongside when she finally touches. Fenders or puddings should be used by both ships and, if possible, should extend far enough horizontally to cover several frames.

In clearing from alongside another vessel, the same precautions should be observed. If the wind is favorable it may be possible to drift away from the anchored ship and go out ahead or astern as desired. If this cannot be done, it is usually handier to spring the stern out and back away, but when going out astern care must be taken not to rake the anchored vessel's side with the bow.

11.19. Destroyers and Destroyer Types. More naval officers learn practical shiphandling in destroyers than in any other type of vessel. This is especially true of coming alongside, as destroyers are often required to dock, go alongside tenders, or secure in nests at a mooring buoy. For this reason, it is well to note carefully some of the peculiarities of the type.

They are high-powered in comparison to their displacement and respond quickly to the engines. They have plenty of backing power. With one engine going ahead at one-third or two-thirds speed and the other backing, at the same speed, they will normally make headway if the backing revolutions have not been standardized. Destroyers have a narrow beam compared to their length; consequently the propeller shafts are close together. The fact that most of the after deadwood has been cut away gives these ships a small turning circle.

Most destroyers have more surface exposed to the wind forward than aft. This construction acts as a permanent head sail and gives the bow a tendency to fall off before the wind and the stern a tendency to back into it. The light construction of destroyers makes it imperative to avoid heavy pressures and sharp blows on their hulls when coming alongside. There is an understandable fascination in handling destroyers which often leads to the taking of unnecessary chances. A good destroyer officer is one who handles the power at his disposal daringly when he needs to do so, but does not invite disaster by rashness. It happens occasionally that an engine will not follow the signal through fault of personnel, and engine order telegraphs have been known to break down while on full speed ahead or astern. Should such an accident happen when the commanding officer is charging into a landing at high speed and trusting to his backing power to stop in time, merely to show himself to be a smart shiphandler, the result may be a smashed bow or some worse accident caused not by an effort to perform some important service but merely by bravado. Situations are sure to occur when the extra power available must be depended upon. It is the height of folly to invite more of them than necessary. Handle a destroyer with caution normally, and with boldness when necessary.

The light fittings, large power, and small lines make it especially important to exercise care in warping or springing around piers. It is often necessary to work the engines in opposite directions with great power, but great strain must not be brought on the lines by imparting motion to the vessel.

The speed to be used in approaching a pier should be in keeping with the space available ahead or astern of the landing and with weather and harbor

conditions. It often happens that the landing must be made when other vessels are moored ahead and astern of the assigned berth.

The pier should be approached at a slight angle (10 to 20 degrees) slowly but steadily, and the engines stopped with sufficient headway to overrun the landing slightly. When it is certain that the ship's momentum is sufficient to carry the bow into heaving line distance, the engines are stopped. Heaving lines are passed as soon as possible, and the mooring lines hauled ashore. The engines are worked to bring the ship in to a securing position, care being taken that springs and breast are properly led and that neither bow nor stern is brought in too sharply, because any localized pressure may result in damage to the frail shell plating.

When the current is running strong and parallel or nearly parallel to the pier, the wind may be considered of secondary importance, for the destroyer is long and narrow and when placed at an angle to the axis of the current will rapidly be carried toward or away from the pier, depending upon that angle.

If the current is forcing the ship on to the pier, as will often happen if piers are athwart the stream, it is important that engines be maneuvered to keep squared up with the pier as the ship drifts in with the current. Under such circumstances sufficient fenders must be ready in place to avoid serious local damage that may be caused to the shell plating.

If the current is running away from the pier, speed must be used, and lines must be got out smartly. Once the lines are out, the stern must be brought in by springing upon the bowline and by skillful use of engines and rudders.

To make a landing with a fair tide is very difficult, as the slightest cant toward the pier will bring the current under the inboard quarter. This force will require two-thirds or full speed of engines and lines to bring the stern in, especially if strain be brought on a forward line which is an error commonly made (every destroyer officer learns that it is useless to attempt to spring in on a bow spring with fair tide). The ship should be brought as nearly parallel to the pier as possible, preferably with a slight cant outward, and the after lines got out smartly and held. If a line can be secured aft, it will act as a spring, and the current will bring the ship in readily. The bow will take care of itself.

Going Alongside a Ship at Anchor. This is very similar to going alongside a pier except that conditions of wind and current to be met are usually more favorable. The destroyer must keep clear of an overhanging stern or of any projections from the side of the vessel approached and if possible select a part of the ship's side where there are no projections. A whaleboat or a triced-up accommodation ladder may inflict serious damage to the destroyer's upper works. The greatest danger is the yawing of the vessel at anchor. Destroyers yaw very freely when anchored and riding to wind or current.

There is rarely any difficulty in going alongside another vessel at anchor. The fact that she is at anchor makes it reasonable to suppose that there will be ample maneuvering room astern, except when she rides with her stern close

to the beach. The approach should be made fairly well clear with a slight cant inward, and the stern should be brought in and the bow carried out by backing the outboard screw and by use of the rudders as forward lines are passed. Here a spring leading forward from the after forecastle chock of the destroyer can be held and the ship breasted in easily by the current. Care must be exercised not to get the current on the inboard bow. Unlike the situation in going alongside a pier, the forward lines are the more important, for the stern will be taken care of by the wind or current to which the anchored vessel is riding. The engines and rudder can be used to assist in paralleling the two vessels as they draw together.

If a destroyer must approach a nest or tender at a wide angle, the bow should be placed about the width of the destroyer from the bow of the outboard destroyer or tender. The destroyer should then be stopped. A bowline should be sent across and held as a pivot, but not hove in until the ships are parallel. The approaching destroyer now goes ahead one third or two thirds on the inboard engine after the rudder has been put over, hard, away from the nest. The powerful turning force of the discharge flow from the ahead propeller against its rudder is to be utilized. The outboard engine is backed at the same speed and changed as necessary to prevent gaining head or sternway. After the ship is parallel to the nest, the bowline can be hove in assisted by a stern line, and a gentle landing made.

11.20. Tugs and Pilots. Normally a ship's master or commanding officer will have a pilot aboard when tugs are used to assist in shiphandling. There may be times, however, when the commanding officer must direct the tugs himself. For this reason Fig. 11.4 is shown. These tug signals are those officially adopted as standard by the Navy, although some local variations will undoubtedly persist. It is always advisable to confer, when practicable with the tug skipper, before the operation, agreeing on the signals to be used, methods of making fast the tug, etc.

11.21. The Mediterranean Moor. The Mediterranean Moor (Med Moor) is essentially a method of mooring a ship perpendicular to a mole or pier using lines to secure the stern and two anchors to hold the bow in place. As the name implies, the Med Moor is used almost exclusively in many Mediterranean ports where pier space is at a premium.

This type of moor has several advantages. First, it saves space in a harbor or port where pier space is small. Second, it provides a strong moor for high winds and rough weather. Third, it eliminates many of the problems associated with mooring alongside in nests. Fourth, each ship has its own brow to the pier. The Med Moor has two major disadvantages. There is a strong possibility of anchors becoming fouled with other ships when trying to get under way. For this reason it is often advisable to get under way in inverse order of entering port. The second disadvantage stems from the first in that it is difficult to get under way quickly in a crowded harbor.

TUG BOAT SIGNALS

HAND WHISTLE (Police Type)

FROM STOP TO HALF SPEED AHEAD	1 BLAST
FROM HALF SPEED AHEAD TO STOP	1 BLAST
FROM HALF SPEED AHEAD TO FULL SPEED AHEAD	4 SHORT BLASTS
FROM FULL SPEED AHEAD TO HALF SPEED AHEAD	1 BLAST
FROM STOP TO HALF SPEED ASTERN	2 BLASTS
FROM HALF SPEED ASTERN TO FULL SPEED ASTERN	4 SHORT BLASTS
FROM HALF OR FULL SPEED ASTERN TO STOP	1 BLAST
CAST OFF, STAND CLEAR	1 PROLONGED 2 SHORT

Notes:

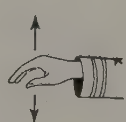
1. A blast is 2 to 3 seconds in duration.
   A prolonged blast is 4 to 5 seconds in duration.
   A short blast is about 1 second in duration.
2. In using whistle signals to direct more than one tug, care must be exercised to ensure that the signal is directed to and received by the desired tug. Whistles of a different distinct tone have been used successfully to handle more than one tug.
3. These signals may be transmitted to the tug by flashing light. However, flashing light signals should be restricted to use only when hand whistle or hand signals cannot be used.
4. Normally these whistle signals will be augmented by the hand signals given below.

HAND SIGNALS

HALF SPEED AHEAD OR ASTERN—Arm pointed in direction desired

FULL SPEED (Either)—First describing arc (as in "bouncing" an engine telegraph)

DEAD SLOW (Either)—Undulating movement of open hand (palm down)



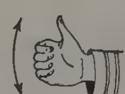
STOP (Either)—Open palm held aloft facing tug

TUG TO USE RIGHT RUDDER—Hand describing circle as if turning wheel to right (clockwise) facing in the same direction as tug

TUG TO USE LEFT RUDDER—Hand describing circle as if turning wheel to left (counterclockwise) facing in same direction as tug

TUG TO RUDDER AMIDSHIP—Arm at side of body with hand extended, swung back and forth

CAST OFF, STAND CLEAR—Closed fist with thumb extended, swung up and down



Note: Tug shall acknowledge all of the above signals with one short toot (one second or less) from its whistle, with the exception of the backing signal which shall be acknowledged with two short toots and the cast-off signal which shall be acknowledged by one prolonged and two short toots.

FIG. 11.4 TUG SIGNALS

This discussion will be limited to the destroyer. Cruisers and merchantmen also utilize the Med Moor. Carriers, however, usually anchor outside the harbor due to limited maneuvering space.

Since the Med Moore is made perpendicular to the pier, it is important that the conning officer determine how far from the pier the anchors will be dropped. The first consideration is the length of the ship. The destroyer is about 390 feet long—130 yards. Next, it is necessary to determine the scope of chain to be used. The shortest chain on a destroyer is 105 fathoms. In making the Med Moor, it is necessary to choose a scope of chain that will allow enough room from the pier for the ship to maneuver freely but allow a margin for error while using the anchor. In general, 75 fathoms is chosen for a destroyer and this allows a reserve of 30 fathoms. Thus we find that the drop distance from the pier is equal to the length of the ship plus the scope of chain (75 fathoms equals 150 yards)—280 yards.

With this distance determined, the conning officer takes a course approximately parallel to the pier. Speed is reduced so that when the ship is approximately 50 yards short of the position abreast of the berth, it has only bare steerageway. At this point the outboard anchor or the one opposite the pier is dropped from the wildcat. If the starboard anchor is dropped, RIGHT full rudder and a twist on the engines is applied so as to keep the anchor chain clear of the ship. The starboard anchor chain is veered until the ship reaches a point 50 yards on the opposite side of the berth. At this time, the other anchor is dropped. Since a destroyer has only one wildcat, the first anchor is dropped from it so that the scope of chain may be shortened at any time and the other is dropped from the compressor. The compressor is a movable constriction in the chain pipe which serves to check the anchor chain. Then the second chain is veered and the first taken in while the ship twists and backs into the berth. To obtain its final position the ship backs gently against the catenary of the anchor chain which is on the wildcat. When the moor is completed, there should be an equal amount of chain to each anchor and in an optimum situation, an angle of about 60 degrees between the anchor chains. When the ship is close to the pier, the conn is generally shifted to the fantail where the distance to the pier can be obtained more accurately. The stern is secured to the pier with a stern line and quarter lines which are crossed under the stern. A stronger moor may be obtained by using the towing line as the stern line and reinforcing the quarter lines with wire. Once the stern line is secure, the moor is tautened by heaving in and equalizing the anchor chains. There should be moderate strain on the anchor chains and they should be standing well out of the water so that a wind from the bow will not damage the ship.

When getting under way, the ship will use its engines to keep its stern perpendicular to the pier and will heave up on the second anchor dropped. This anchor is "heaved right on in." Then the remaining anchor is heaved to short stay and then "heaved on in." The ship is then free to proceed out of port.

Destroyers often moor in a Med Moor nest. This is accomplished by having the first ship drop her inshore anchor only and then back into a stern first position against the pier. Remaining DD's moor alongside with standard mooring lines to the other ships. The last ship in drops her offshore anchor only and twists into the stern first position. The final result is a nest which is moored in a Med Moor.

In some harbors, such as Barcelona, Spain, a gale which sends seas into the harbor entrance will cause a rapid rise and fall of the sea level within the

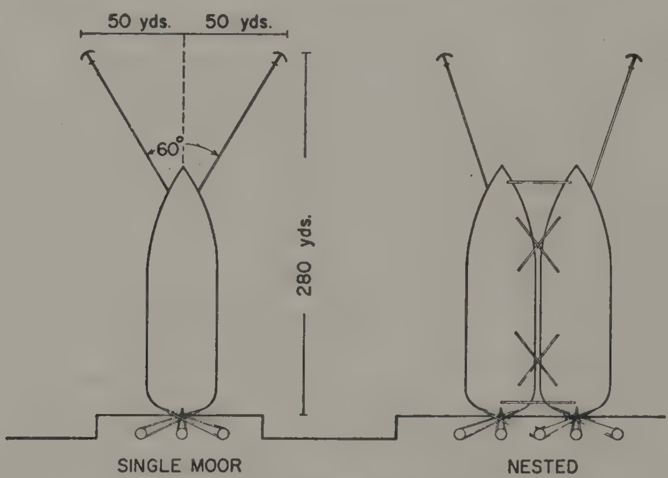


FIG. 11.5 MEDITERRANEAN MOOR

port. A firmly moored ship under these circumstances may part her lines to the wharf, and the resultant fore-and-aft surging may carry away the brow. It is recommended that, if circumstances warrant, the brow be removed and all lines to the wharf be eased or taken in. A line or two tended on a winch will usually keep the stern under control as the ship surges. Nylon lines with their greater elasticity should be of help.

There is one important precaution to take when Med mooring a large ship. The stern line, holding the stern in close to the pier against the strain of the anchor chain, must never be led from the aftermost chock straight down to the pier. In bad weather, as the stern rises and falls, a straight, short lead to the pier will either part or will pull out or rupture the bollard. Instead, lead tow stern lines aft from each quarter chock well forward of the stern chock. These lines will be longer, have more "give" and will make a smaller angle with the pier. In addition, of course, after spring lines should be led out from the stern chock, crossed and secured well down the pier on each side, preventing the stern from moving side to side.

12

Towing and Salvage

The rescue of ships in distress and the refloating of those who have grounded is a highly specialized calling to which men devote their lives, but every seaman should have a basic knowledge and understanding of towing and salvage. This chapter provides all that the average seafarer need know in order to tow or be towed in an emergency or to meet the emergency of a sudden grounding.

Towing

12.1. The Towline. Generally speaking, the longer and heavier the towline, the easier the towing will be. A decided dip or catenary gives the same advantage here as in the case of a vessel at anchor riding with a good scope of chain. The weight of the catenary acts as a spring, preventing variations in the tension from being thrown upon the towline in sudden jerks.

Wire rope has proved very satisfactory for heavy sea towing. The advantages of using wire rope are that it is convenient for casting off, takes up comparatively small space when stowed, and does not deteriorate if properly dried and oiled before stowing.

Nylon is satisfactory for light or moderate towing. It is heavy enough to give a good dip when used in sufficient length, but it is not too heavy for convenient handling. Nylon is popular for relatively light towing because of its resiliency, ease of handling, and long life.

For towing a ship as small as a 2200-ton destroyer in rough weather—and it must not be overlooked that rough weather may be encountered in almost any towing operation—the full length of a 6- or 8-inch nylon hawser or a 1-inch diameter wire rope will be none too much.

Where the tow is a vessel whose displacement is comparable with that of a cruiser or aircraft carrier, the towline should be made up of 2½- or 2¼-inch diameter wire rope connected to a good length of her own anchor cable. The length that is needed will vary with circumstances, but it is far better to have too much than too little.

A point of some importance in towing in a seaway is to keep the ships in step. In other words, use such a length that they shall meet the waves and ride over them together. If the length of the line is such that one vessel is in the trough of the sea as the other is on the crest, the line will slacken for a moment and then

tauten with a sudden jerk; whereas if they meet the waves at the same time, the tension of the line will remain comparatively steady.

12.2. Securing on the Towing Ship. In securing the towline, consideration must be given to the possible necessity for letting go in an emergency.

For convenience in letting go, it is desirable to have a break in the line near the stern. It would be advisable to have a shackle connecting two parts of the line at or near this point, together with some arrangement like a pelican hook for slipping quickly. The possible whip of towlines and bridles when released at any point may be overcome by the use of preventers.

If the towing ship is comparatively large and has a chock at the stern, the line should be brought in through it. It is a good plan to use a short length of chain for the lead through the stern chock, shackling outside to an eye in the end of the towing hawser and inside to a towing bridle. The chain through the stern chock not only takes the chafe, but by its flexibility does away with the dangerous nip which might be thrown into wire if the tow chanced to take a rank sheer onto the quarter.

Where the chain is not used for taking the chafe in the stern chock, the towline must be fully protected by chafing gear which should be a long and bulky pudding. The stiffness of such a puddening reduces the sharpness of the nip which, without the pudding, would be thrown upon the towline from time to time by the sheering of the ships. A towline leads down, not up. Worm, parcel, and serve manila. Use canvas, hides, burlap, and old rope on wire towlines.

Where the strain is not too heavy to be taken by one pair of bitts, the towing line may be secured as shown by Fig. 12.1. Figure 12.1(A) shows how a towrope should not be secured. Here the greater strain comes on the left bitt, which might result in the left bitt lifting and being torn out.

In Fig. 12.1(B) the greater strain is taken by the after bitt and, though the forward bitt has some strain, they should hold under ordinary conditions.

When one pair of bitts is not strong enough, the line can be taken to as many as three sets of bitts if available. To divide the strain it is advisable to take one turn around the first bitts, two around the second, and three around the third, thus leaving the line free to render slightly and so equalize the strain.

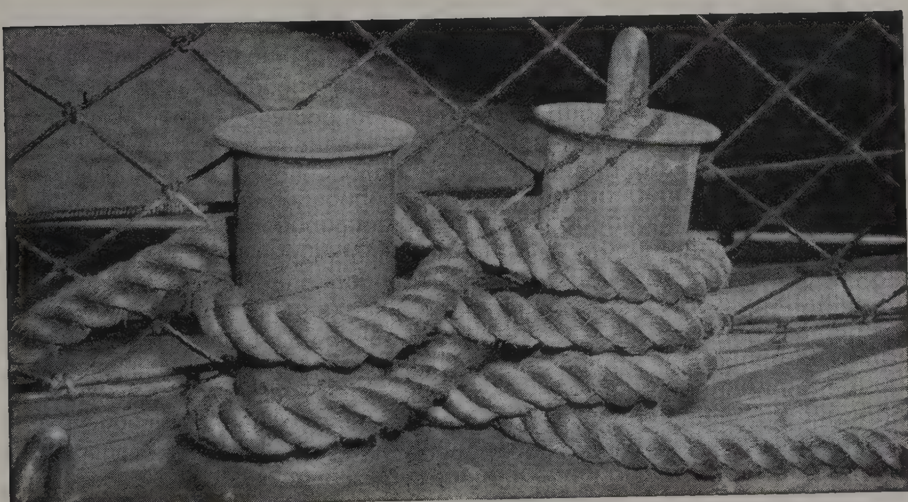
Where pelican hooks are used for letting go, as shown by Fig. 12.2, the strain is taken momentarily on the hook, relieving the shackle so that it can be disconnected and towing hawser slipped when ordered. This arrangement entails practically no delay. An arrangement with a pelican hook taking the steady strain of towing offers the quickest emergency release.

Where pelican hooks are not used, a strap may be used on the wire or chain outside the shackle, and a heavy purchase hooked to the strap and taken to a winch. For letting go, the strain is taken by the winch long enough to disconnect at the shackle, after which the strap is cut as ordered (Fig. 12.2(C)). A preventer must be used to prevent a dangerous whip upon letting go.

There are some conditions under which it is convenient to use a span on the towing ship. The two parts are brought in through the quarter chocks. Generally

speaking, this makes it rather easier for the towing ship to steer, and the advantage gained in this respect may become important in cases where a small ship is dealing with a heavy tow. Where the line leads from a chock directly over the rudder, it binds the stern so that it can only swing in obedience to the rudder by dragging the tow with it. A large ship can take care of this situation by the power of her steering gear, assisted if necessary by the propellers; but a

(A)



(B)

FIG. 12.1 LEAD TO TOW. (A) The wrong way to secure a towrope. (B) The right way to secure a towrope. (Direction of tow →.) *Official U.S. Navy Photographs*

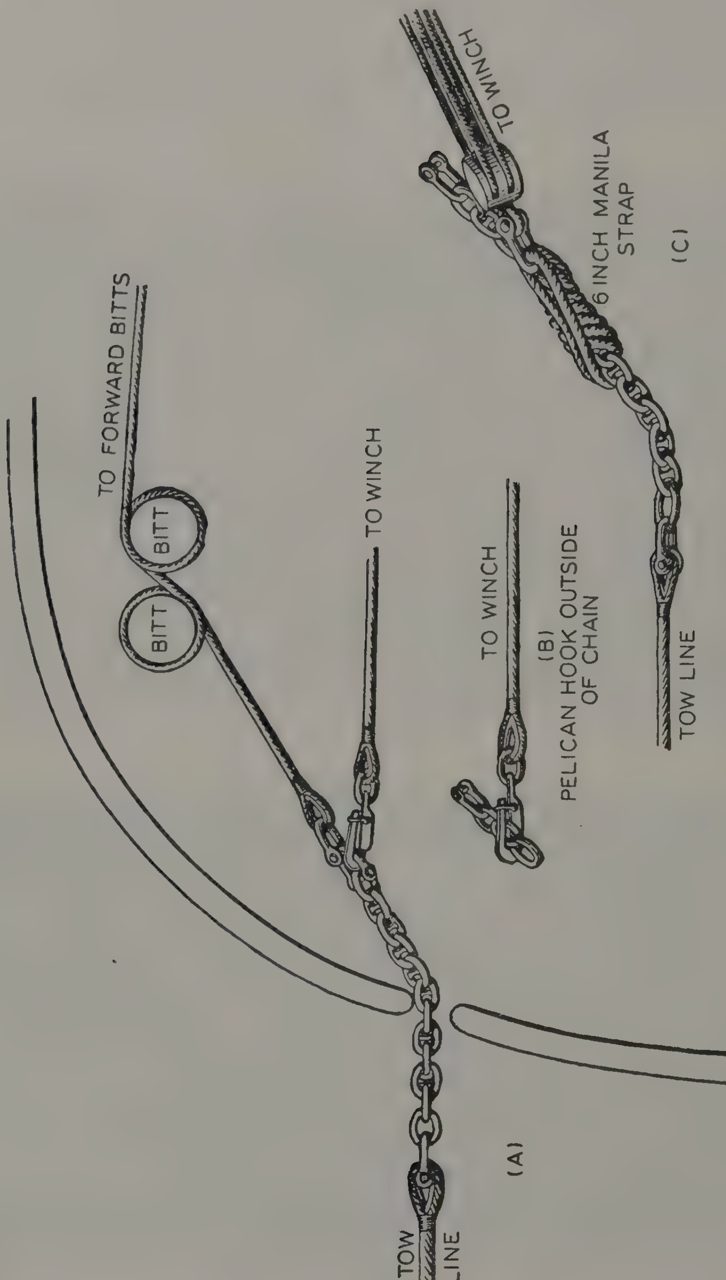


FIG. 12.2 TOWING BY BITTS

small ship with a heavy tow and with the line leading through the stern chock will steer very sluggishly if she steers at all. Tugs which are specially fitted for towing have their bitts well forward of the rudder to allow the stern to swing; the fittings abaft the bitts allow the line to sweep freely across from one quarter to the other.

Where a span is used, it may be of chain, wire, or manila. In this as in other cases, arrangements must be made for letting go quickly in emergencies.

A convenient plan is to bring the towline in through a quarter chock and bend a hawser from the other quarter to it at such a point outside that the two parts shall form a span of convenient length. The lines may be secured around bitts as previously described. This plan has the advantage that by letting go the second line we get rid of the span at once and have to deal only with the towline itself.

12.3. Towing Engines. Vessels designed especially for towing, such as seagoing tugs, are fitted with towing engines which carry the towline on a drum and pay it out and haul it in automatically to keep the towing tension constant. For a steam towing engine this tension is controlled by a differential valve which is set to remain centered with any desired strain on the towline. If the tension rises momentarily, the valve moves in one direction. The drum revolves and pays out line until it has the required strain, and then the valve centers itself and the drum stops revolving. If the tension decreases, valve and drum move in the opposite direction, reeling in the line until the proper tension is restored. With electric towing engines an automatic controller accomplishes the same result. In this way the line is payed out or reeled in just enough to meet the condition prevailing at any given moment, and the average length of towline remains virtually constant. The drums of towing engines must be very rugged and are fitted to heavy foundations built into the frame of the ship. They are placed at a distance from the extreme stern, the pivoting point, in order to lessen the interference with the steering of the towing vessel. Guiding chocks and bollards and a long quadrantal chock for the towline extending along both quarters of the ship at deck level are installed for the same reason.

The standard towline for vessels fitted with a towing engine is 300 to 350 fathoms of wire rope 1½ inches in diameter. It is stowed on the drum of the towing engine when not in use. When towing is finished, the towline is cast off by the towed vessel and automatically reeled in by the towing engine. The eye of the towline is generally fitted with a shackle and open link for securing aboard the tow.

12.4. Securing the Tow on Board. On board the tow the hawser is usually secured to the anchor cable, although there may be many conditions under which some other arrangement will be provided. If the anchor cable is not used, it is desirable to use at least a short length of chain to take the chafe in the chock in the same manner as already described for securing on the towing ship.

Where the anchor cable is used, the hawser is secured or shackled to it and

the cable veered away to the desired length, after which the windlass brakes are set up and springs or chain stoppers are used to take the real strain of towing, as in Fig. 12.3. It is well to have a shackle between the windlass and the point to which the springs or chain stoppers are secured and to keep tools at hand for unshackling if it becomes necessary to let go in an emergency. Generally speaking, the tow should not let go in this way except in case of extreme emergency, as the line weighted with a considerable length of heavy anchor cable would sink immediately, hanging as a dead weight from the stern of the towing vessel. In this position it would be extremely difficult to handle and would be in danger of fouling the propellers. This applies only to cases where

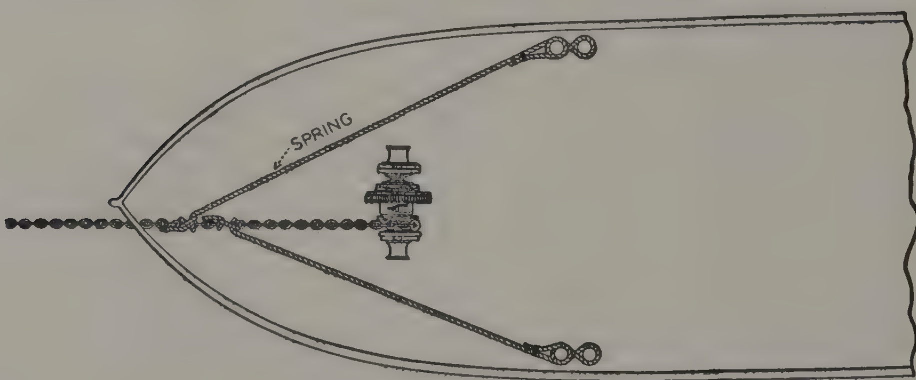


FIG. 12.3 BOW OF SHIP TOWED

the tow is a vessel of some size and where she is towing by her anchor cables. It is evident that, where a large ship is towing a small one, the natural way of casting off is for the tow to let go, which leaves the line to be handled by the large ship.

12.5. Taking a Disabled Vessel in Tow at Sea. In good weather, this maneuver presents no special difficulty and calls for no extended discussion. The lines are run and secured as already described. The towing vessel starts ahead slowly on the course upon which the disabled vessel happens to be heading and uses every precaution to prevent a jerk on the line. It waits before changing course until both ships have gathered way and are moving steadily with a good tension on the towline.

In bad weather, towing should not be attempted unless exceptional circumstances make it necessary. The running of lines in a heavy sea is attended by considerable difficulty, especially if the vessel to be towed is unable to assist by placing herself in a favorable position. Moreover, in really heavy weather, it would be necessary to proceed so slowly that little or no time would be lost by waiting for the weather to moderate.

Disabled vessels lie in different positions relative to the wind, depending on the size and position of the superstructure, the trim and, perhaps, drag due to

damage. If there is more superstructure forward than aft, the vessel will lie with the wind from abaft the beam to astern. Vessels with much superstructure amidships will lie with the wind abeam and those with superstructure aft, such as tankers, lie head into the wind. All such vessels make leeway of 1 to 3 knots and, if lying at angle to the wind, headway or sternway. Vessels down by the head tend to head into the wind and vice versa.

If a tug with a deckhouse forward and a flat stern is the towing vessel, she should approach down wind and just clear of the bow, except when the vessel lies head into the wind. In this case, the approach of the tug is still down wind but just ahead of the vessel, using her engines to keep position and clear. The sketches in Fig. 12.4 show that the tug is able to work close to the disabled vessel and still keep clear by a kick ahead at intervals.

It will be considered in the discussion which follows that one vessel is going to tow another and that the weather is rough enough to call for the use of all reasonable precautions but not rough enough to make towing impracticable. It may be assumed that the disabled vessel will be lying with wind and sea a little abaft the beam, this being the position which a ship usually takes when lying in a seaway with engines stopped. The other vessel places herself on a parallel heading either to windward or to leeward. In considering which of these positions is to be preferred, we must remember that considerable time will be required to run the lines; and that during this time both vessels will be drifting. A vessel which is light will drift faster than one which is loaded, and the drift of a vessel in ballast-trim often amounts to several knots. If the lighter vessel is to leeward, she will drift away from the other and make it very difficult to run the lines. It may be said that, as a general rule, if there is any important difference in the rate of drift of the two vessels, the lighter one should be to windward when the work of running the lines is begun. The towing vessel then places herself to windward if she is drifting faster than the other vessel and to leeward if she is drifting more slowly and on the same heading as the disabled vessel.

Where the difference in the rate of drifting is considerable, the time available for running the lines after the work is once begun will be short at best. Every precaution should be taken to prevent delay, with a clear understanding being established between the ships and all preparations made before the towing ship takes her position. In communicating between two ships, megaphones are of the greatest value. Under any except the most unfavorable conditions they should make it possible to perfect a thorough understanding of what is to be done and how. To a great extent they also may take the place of signals between the two ships after the towing begins, although a code should by all means be adopted and will be useful under many conditions. It is an excellent plan when feasible to send an officer on board the tow to remain there. First acquaint him with the plan to be carried out and provide him with a list of whistle and sight-signals for handling the lines and the ships. If no boats are to be used, a paper may be floated across to the tow giving full instructions and

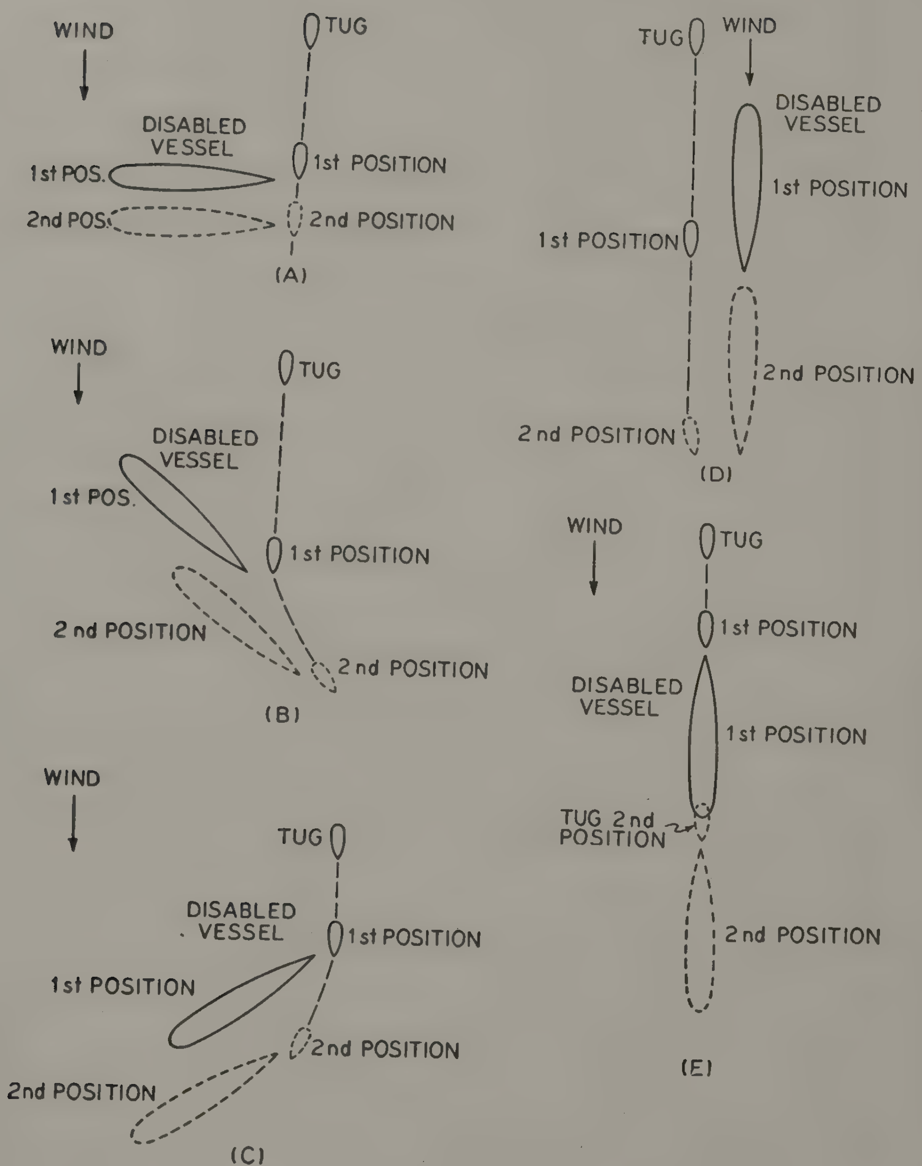

WIND
TUG
DISABLED VESSEL
1st POS.
1st POSITION
2nd POS.
2nd POSITION
(A)
WIND
TUG
DISABLED VESSEL
1st POS.
1st POSITION
2nd POSITION
2nd POSITION
(B)
WIND
TUG
DISABLED VESSEL
1st POSITION
1st POSITION
2nd POSITION
2nd POSITION
(C)
TUG
WIND
DISABLED VESSEL
1st POSITION
1st POSITION
2nd POSITION
2nd POSITION
(D)
WIND
TUG
1st POSITION
DISABLED VESSEL
1st POSITION
TUG 2nd POSITION
2nd POSITION
(E)

FIG. 12.4

a list of the signals. This may be sealed up in a bottle and attached to the rope or the float. Whistle signals are preferable to flags because they can be used at night or in a fog.

The following is suggested:

Code of Sound Signals for Towing

A short blast must not exceed 2 seconds in length.
A long blast must not be less than 6 seconds in length.

I am putting my rudder right	1 short blast
I am putting my rudder left	2 short blasts
Go ahead	2 long
Stop	1 long, 2 short
All fast	2 long, 1 short
Haul away	2 short, 1 long
Let go	2 long, 5 short
Pay out more line	1 short, 2 long
Avast hauling	3 short
I am letting go (emergency)	5 short, 5 short, 5 short

12.6. Handling Lines and Getting Underway. The first line to be run will be a light one by means of which the heavier ones can be hauled across. A 3-inch manila is a convenient size to begin with and, if new, so much the better because it will float freely. If a boat is to be used, it should be lowered with the crew and the greater part of the line in it and made clear as quickly as possible. The line should be payed out as the boat pulls away for the other ship.

The line may be floated alongside the disabled ship without much difficulty. The best way to do this will depend upon circumstances, but a common way is to float a good length of the line by life belts, casks, or any other means and to steam slowly around the disabled vessel, dragging this astern and causing it to foul the disabled vessel. If proposing to take up a position on her weather bow, it is a good plan to steam along to leeward fairly close aboard, cross the stern, and come around parallel to her heading. This will cause the line to foul her stern, which entails a little trouble in shifting it forward, but it leaves the towing ship in position without further maneuvering. Similarly, if proposing to take a position on the lee bow, pass along to windward, cross the stern, and come around to leeward. The line should be picked up without difficulty.

There may be special circumstances which will make it desirable for the disabled vessel to run lines, but under ordinary circumstances it is more convenient for the towing vessel to run them. Having got the first line across, the heavier lines are run and made fast to the anchor cable of the vessel to be towed where possible. A good length of cable is paid out—20 to 45 fathoms is none too much for heavy work—and the line made secure on both ships as has been described. Chafing gear is used liberally wherever it is needed. In the meantime, full instructions about starting are given to the chief engineer, and, when all is ready, the engines are started ahead as slowly as possible and stopped the moment the line begins to tauten out. Then a few more turns are made and so on until the inertia of the tow is overcome and both ships are

moving slowly with a steady tension on the line. The revolutions are then increased little by little, and the course changed gradually as may be necessary. When the tow is finally straightened out and moving steadily, the speed is worked up to that at which it is thought wise to continue.

In all changes of course the tow puts her rudder at first to the side opposite that of the leader and so steers around into the leader's wake.

After settling down to a steady rate of towing, the lines should be examined, the strain divided as evenly as possible, chafing gear renewed wherever necessary, etc. Hands should be stationed night and day to watch the lines on both ships, with axes and unshackling tools ready for slipping hurriedly if necessary. It is well to have a light messenger line between the ships for hauling messages across and for use in running a new line in case of necessity. This line should be left slack and should have ample length to allow for the fact that if the towline parts the leading ship will forge ahead considerably before she can be stopped.

Salvage

12.7. Groundings. Salvage in its broadest sense includes the salvage (recovery) of cargo, the removal of wrecks and the refloating of grounded ships. Only the matter of grounded ships will be discussed herein since the salvage of cargo and the removal of wrecks involve highly specialized techniques not of major interest to seafaring men generally.

The first thing the captain or salvage officer of a grounded ship should do is to notice whether the ship is lively, i.e., is affected by the swells. If so, it may be possible to refloat her at once by sallying ship, backing full speed, and pulling by any large tugs or other vessels which may be available. Should these measures be unsuccessful, the next step is to send out an anchor astern with a wire to hold the ship in her original grounding position. Put and keep a heavy strain on the wire. Swells tend to force ships farther up the beach and to turn them broadside to the sea.

The next step is to sound all around the ship to determine what part of the ship is grounded and the loss in draft. The average loss in draft times the tons per inch immersion as taken from the ship's curve will give the total loss in buoyancy in tons. This weight is the problem. The loss in buoyancy must be reduced to the point where the pull of beach gear and tugs will be sufficient to refloat the ship.

Salvage men have calculated that a pull of about 30 percent of the remaining lost buoyancy is required to refloat a ship aground on a sandy bottom with a gentle slope; 50 percent when the bottom is hard or gravelly; 60 to 80 percent for coral; and 80 to 150 percent for rocky bottom. A large amount of weight will probably have to be removed from the ship to reduce the lost buoyancy to a manageable amount.

Personnel, fuel, and water can be removed more easily and quickly than

stores, cargo, ammunition, spare parts, and guns. The decision to remove any or all of these weights, as well as when to move them, will depend on a number of factors. In all probability the determining factor will be the weather for offshore groundings, although the state of the tide at grounding and the time of the next tide or perhaps the next spring tide may be equally important. In some parts of the world the range of the tide is so great that ships grounding at part tide are refloated at high tide. Where the rise and fall of the tide is not that great, the time and date of the next spring tide may be the deciding factor as far as time is concerned.

Some other physical conditions must be known and weighed also. Was the ship fully loaded? What compartments, bottoms, and tanks have been holed? What kind of a bottom is under the ship? Currents can scour the sand from under a ship in one place and pile it up in another. While all the physical conditions are being compiled and analyzed, it is wise to send out additional anchors to hold the ship in her grounding position.

12.8. Planning and Methods. The planning must be carefully done so that the weights to be moved, the equipment to be used, and the dredging to be done will be coordinated and completed at the end of the time available. Some fuel and water will be required for engines. All of the weight removed cannot come from the double bottoms and fuel tanks or the stability of the ship may be adversely affected. Many men are required to handle stores, spare parts, cargo, and ammunition. These men must have deck space to handle these items and space alongside for the barges to receive the stores, fuel, etc. The plan must coordinate the times for removing weights, for laying out the beach gear on deck, for dredging alongside, and for receiving barges.

The following measures may be available and used:

1. Remove fuel.
2. Remove water.
3. Remove cargo.
4. Remove stores.
5. Remove spare parts.
6. Remove ammunition.
7. Remove guns or missiles.
8. Transfer some men.
9. Dredge and scour alongside.
10. Tunnel under the ship.
11. Rig pontoons.
12. Rig beach gear.
13. Expel water from holed compartments.
14. Services of salvage vessels.
15. Services of tugs.
16. Twist the ship.

When large ships are stranded, a trench can be dredged along each side of the ship if the bottom is sandy or muddy. The trench should be made deep enough to receive a large part of the sand and mud upon which the ship is resting. If this sand and mud will crumble and move into the two trenches, the ship may be floated in her grounded position. This method has been successful occasionally.

European salvage men have had some success with scouring the bottom from under the ship. A small vessel with her propeller well immersed is secured to the grounded ship in such a position that the discharge current from her pro-

peller scours the sand from under the ship. In some cases the engines of the ship itself have been used to remove sand and mud from under the ship. Care must be taken that a new shoal is not formed astern. The engines cannot be operated in the other direction, i.e., astern, for very long because sand may be washed under the ship and the problem of refloating made more difficult.

Divers with high-pressure hoses are used, after trenches have been dredged, to start the movement of sand and to wash away the remaining sandy supports. Divers are used also to tunnel under the ship so that the chains which hold the pontoons in place can be rigged.

The Navy stores and maintains large pontoons at certain yards on both coasts. These pontoons have a lifting capacity of some hundreds of tons. They have been used to reduce the amount of the lost buoyancy of grounded ships. The pontoons are rigged under the quarter and bows with regard for the propellers, shafting, rudder struts, and skeg which are easily damaged.

It is probable that certain compartments were flooded when the ship grounded. These compartments can be nearly freed of water by forcing air into the compartment. Care must be taken that the pressure of the air does not rupture the compartment. The pressure of the air should be a little higher than the pressure of the water due to the distance below the surface.

12.9. Beach Gear. One of the most useful pieces of equipment now available to a grounded ship is beach gear. It is in reality a development of the older methods of laying out anchors and cables for salvaging ships. The present-day beach gear consists of:

1. An 8000 lb. Ells anchor fitted with a crown line and buoy for breaking loose and recovery.
2. 15 fathoms of chain attached to the anchor.
3. Two or three 100-fathom wire cables of galvanized plow steel.
4. A shot of chain.
5. Shackles.
6. Wire stoppers.
7. A four-sheave wire tackle.

The anchor, sometimes backed by a second one, is planted well out and in the direction the ship will have to move when it is refloated. The chain is used between the wire cables to keep the direction of pull as nearly horizontal as possible. The end of the second wire is led through a chock or an opening cut in the side of the grounded ship. The tackle is laid out on deck and aligned with the wire so that the pull when applied will be straight with no nip or bend in the wire. The hauling part of the tackle is now led to a ship's winch or to a salvage winch installed to supplement the ship's gear. In the salvage of the *Missouri,* nine sets of beach gear were used in addition to three sets laid out from each of two salvage vessels which were pulling too. Each set of beach gear can exert a pull of 50 to 60 tons. Such gear kept under heavy strain has been a large factor in salvaging many vessels.

The services of salvage vessels are valuable because they have a large amount of gear, including beach gear, which can be used. The personnel are trained for salvage work and their anchor gear and winches are oversized.

There is a tendency to use any tug which is near when a ship grounds, under the impression that prompt, energetic action is desirable. Often this is not true because small tugs are of little use for pulling on large vessels aground. Tests of the pulling power of tugs have been made, and it has been found that they exert a pull of about 1 ton per 100 horsepower. Large seagoing tugs have a pull of 10 to 15 tons and Naval Fleet tugs about 30 to 35 tons.

It is very probable that the lost buoyancy of a large ship is so great that she exerts a pressure of hundreds of tons on the bottom. The sand under her has been packed so tightly that it has a consistency of low-grade concrete. We may say that the ship exerts a powerful suction on the bottom. One of the ways of breaking this suction has already been mentioned, namely, the crumbling of the sand under the ship into dredged trenches alongside. After much of the weight of lost buoyancy has been removed, and all preparations completed to refloat the ship, large tugs are used occasionally to twist the ship and thus break the suction. Small tugs are useful now to hold large tugs and salvage vessels in position to exert their best pull. In these operations cross currents can be very annoying.

The salvage plan should include the measures necessary to ensure the safe voyage of the refloated ship to the nearest base or shipyard. Anchors and chains must be returned, the holed compartments should be patched and shored, and the stability and trim of the ship must be satisfactory. If her engines cannot be used, she will have to be towed. These measures may require the reloading of fuel, water, stores, and even ballast in order that a further disaster may not occur.

The experiences of seamen show that oil prevents the crests from breaking and delays the development of the smaller waves which are superimposed on the larger ones. Only the underlying swell remains. The beneficial action of oil is due to the increase of surface tension.

12.10. Rescuing the Crew of a Wreck at Sea. There are no hard and fast rules which can be laid down for rescuing the crew of a wreck; only what is considered the best practice by experienced and capable seamen may be stated. So many elements control the application of the general rules, such as sea, wind, urgency of immediate assistance, maneuverability of the assisting ship, and the training and experience of the boat crews, that each case must be decided according to circumstances.

After having made contact and established communications, find out how urgent the case is and how much help may be expected from the crew of the wreck. If it is at night and weather conditions indicate an improvement or at least no worse weather, and the master of the disabled ship feels he can hold on and you feel you can maintain contact, wait for daylight.

Under any circumstances, when the rescue begins, determine the compara-

tive drift of the two ships and whether or not there is any wreckage about the disabled ship. If there is wreckage, discern how it will hamper your boat work. If your ship drifts faster than the disabled ship, go to windward; but if the opposite is the case, go to leeward. Both ships should distribute oil freely. If for any reason the wreck cannot use oil, the rescuing ship should steam around her and run oil freely to create a slick into which the wreck will presently drift.

Before the rescue work begins, the boat should be equipped with two sharp hatchets in brackets, one at the bow and one at the stern; one ring life preserver with stout heaving lines made fast; two spare life jackets stopped with sail twine under each thwart; two spare oars; two small oil bags; and a small tin of storm oil.

If the weather is very rough, extreme precautions will be called for in lowering the boat and getting her clear. The ship should be held with the sea on the bow to give a lee for the boat and to reduce rolling as much as possible. The crew, with life belts on, is lowered in the boat. Frapping lines are used around the falls to steady the boat, and fenders are rigged to prevent the boat from being stove in if she swings in heavily.

Assuming that the boat gets off and makes the trip to the wreck in safety, the officer in charge must decide how he will establish communication and take off the passengers and crew. It is out of the question to go alongside to windward; and if he goes alongside to leeward, not only is there a risk of being stove by the wreckage which is likely to be found floating under the quarter, but there is the much more serious danger of being unable to get clear of the side again. A ship lying in a seaway with engines stopped drifts to leeward at a rate which is always considerable and may amount to several knots. A boat alongside such a ship to leeward is in exactly the same position as if she were alongside a dock against the face of which a strong current is setting. As a rule the boat must never be brought actually alongside the wreck. She may either lie off to windward and keep well clear and hold up head to sea or to leeward and hold on with a line from her bow to the wreck. If obliged to go alongside, the stem may be allowed to touch, with all being ready to back off if the boat shows a disposition to get broadside-on. The people on board the wreck put on the life belts, go down a line one at a time, hand over hand, and are hauled into the boat. In most cases the most favorable point for working will be under the lee quarter or the lee bow. This depends upon the way the wreck is lying with reference to the sea. It is sometimes possible for people to lower themselves or be lowered to a boat from the head-booms or from an overhanging main-boom when they could not be rescued in any other way. So serious is the question of avoiding actual contact with the wreck that many officers consider it best for the rescuing ship to go to windward and drop the boat down with a line, putting only two or three men in the boat.

13

Boat Handling and Helicopter Operations

As ship's boats are normally designed for a variety of purposes, their handling will be discussed under the various conditions in which they are used.

The power boats of a ship, including landing craft, do the greatest part of their work in port or off the beach, running from ship to shore. Under these circumstances it is normally a safe and simple matter to hoist and lower them with a crane or boom. When hoisting or lowering at sea or at anchor during rough seas, certain precautions must be observed in order to prevent the boat from being stove in, swamped, or the crew thrown overboard. If these precautions during operations in rough seas are understood and observed at all times, there should be no difficulty in hoisting and lowering boats under more favorable sea conditions.

With the exception of those boats which are provided with their own davits, large boats and heavier landing craft are hoisted and lowered by means of boat cranes or booms which hook on the slings rigged in the boat. The slings are attached to hoisting eyes which are built into the strongest sections of the boat. Davits which are used for many of the smaller boats can be considered as nothing more than two cranes which perform the same job in a slightly different manner.

Davits are used to swing the boat to the lowering position and then after it has been hoisted to swing it back on board. The actual raising and lowering could be done by manning the boat falls with sufficient men. However, the falls are generally taken to some source of power to accomplish raising the boat and then to a belaying point, such as a cleat or the gypsy head of a winch, for lowering.

The various types of davits used have been described in Chapter 6 and will not be discussed further here, with the exception of the radial davit, which is the most common aboard small combatant ships and is also the most difficult to use.

Prior to swinging the boat out, the boat plug is checked and reported to the man in charge as being in place. If the boat is resting in chocks, it is hoisted clear of the deck and all preparations made to swing it out. When it is clear of the deck, the boat is shifted aft so that the bow will clear the forward davit.

This davit is rotated and the bow pushed out so as to clear the side. The rear davit is then rotated and the stern pushed over the side. The boat is then ready for lowering. This type of davit provides a rapid and simple method of swinging out small boats such as the motor whaleboat and the pulling whaleboat.

Care must be taken in hoisting the boat out of the chocks. In hoisting it clear, it is advisable to hoist the stern of the boat first to avoid any danger of striking the propeller or rudder against the deck. After the stern has been hoisted clear, the commands are "avast heaving" and next "pass the stopper."

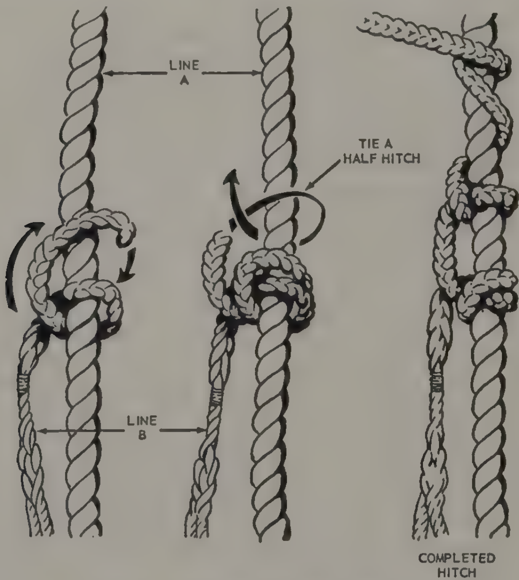


FIG. 13.1 STOPPING-OFF THE FALL

The hauling part is then stopped-off as shown in Fig. 13.1 by means of two half hitches and two or more turns, and by holding the bitter end of the stopper and the fall firmly together by hand. When the stopper has been passed and secured, the command "walk back" is given, and the strain is gradually released on the hauling part and taken up by the stopper. When all the strain has been transferred to the stopper, the order "up behind" is given. The men on the hauling part quickly run forward with the slack of the fall to the davit where the line is belayed on a cleat at the command "belay." Figure 13.2 shows the proper manner of doing this. Emphasis is placed upon passing a round turn first and a half hitch last. It is well to mention here that many seamen prefer to pass two round turns first, in lieu of one, for added protection. This procedure places the weight of the boat on the whole cleat rather than on just one of the horns which could conceivably shear off. When the after fall is properly belayed, the bow of the boat is raised and secured in like manner.

After the boat has been lifted clear of the chocks, the order "launch aft" is

given and the boat is moved aft far enough to let the bow or stem of the boat clear the forward davit. When it is clear, the order "launch forward and bear out" is given. Then, as the bow is pushed out, and the boat is pushed forward, the bow passes over the side and between the davits. When it is far enough forward for the stern to clear the after davit, the command "bear out aft" is given, and the stern is pushed over the side of the ship. The davits are then placed at right angles to the ship, and the boat is ready for lowering.

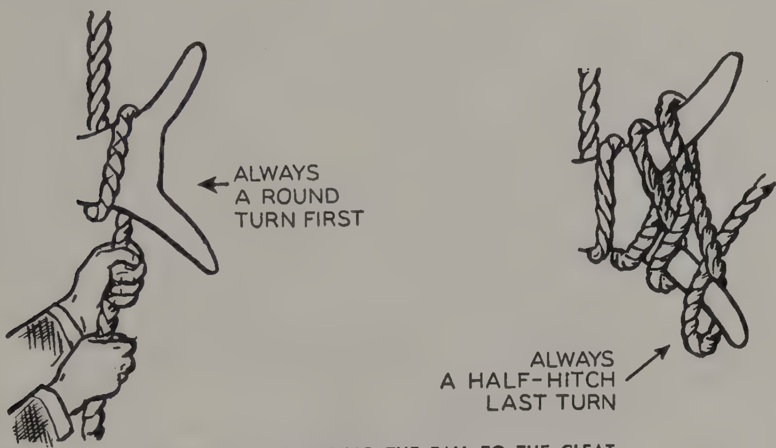


FIG. 13.2 SECURING THE FALL TO THE CLEAT

13.1. Lowering and Hoisting Boats by Radial Davit. *Lowering Away.* Because the placing of the boat in the water when anchored or moored is normally a simple operation of lowering it until it is waterborne, lowering away will be discussed only while under way, as this is the most dangerous and difficult. The proper use of the sea painter and the rudder is essential to keep the boat from being thrown against the side of the ship. The use of the sea painter will be described later in this chapter. In lowering a boat in heavy weather, steadying lines called *frapping lines* (Fig. 13.3) must be used. In using frapping lines, one end is secured to something solid on deck. The bight is passed around the falls and the end is brought back on deck and tended by a turn or two. The purpose in using the frapping lines is to keep the boat from swinging wide as the ship rolls. Another means of keeping the boat from swinging out as the ship rolls is the use of *traveling lizards* (Fig. 13.3). The traveling lizards are kept in hand in the boat, after a turn is taken around a thwart. Under no circumstances are the lizards to be secured in the boat.

When ready to lower, the man in charge of lowering takes a position between the davits. When lowering by means of radial davits, only the most experienced men should be used on the cleats when slacking the falls. Care must be taken to prevent the lines from jumping the cleats. At the command "lower away together" the men on the cleats remove all the turns but the round turn and then gradually pay out the falls. The boat should go into the water

on an even keel or slightly by the stern. If the sea is rough, the boat should be held clear of the water until a trough appears in which to set it down. If the boat is set down on the crest of a wave, the hoisting gear will be subjected to a heavy strain when the sea drops out from beneath the boat. As soon as the boat is waterborne, the command "up behind" is given. At this order the men on the cleats remove the final turns and slack the lines so that the boat will ride immediately to the sea painter.

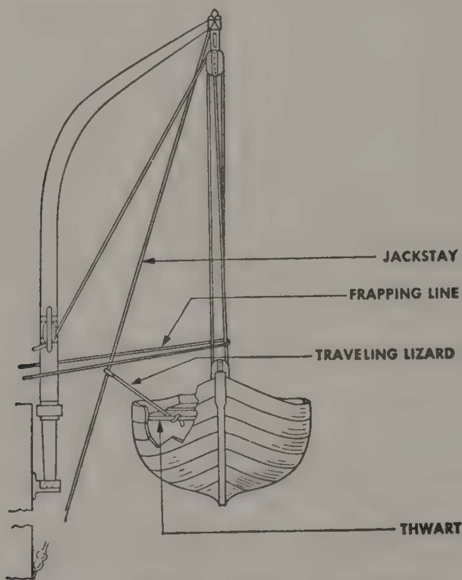


FIG. 13.3 USE OF FRAPPING LINES AND TRAVELING LIZARD

The coxswain of the boat should have his crew fend the boat away from the ship during the descent. Small boat fenders between the boat and the ship will also help. He will have his engineer start the engines during lowering to be sure that they are warmed up. As soon as the boat is waterborne, the coxswain orders the *after* falls cast off, followed by the *forward* falls. He then sheers off and orders the bow hook to let go the sea painter.

To prevent the lower block from tumbling, a nontumbling block is used; i.e., one designed to keep from turning over as it is hoisted back on board and the weight of the boat is no longer on it. However, even with this type of block, care must be taken in bringing it back on board. If the hauling part is pulled, the parts of the falls will not pass through the sheaves, and the block will turn over. Another safety factor is the swivel hook attached to the lower block. This swivel permits the removal of twists in the falls. If an attempt is made to raise the boat without removing the turns, the grind of the turning block may shear the shank off the hook. If not, the friction on the parts of the falls will be so great as to increase materially the difficulty of raising the boat. The block is of the automatic releasing hook type described in Chapter 6.

One thing to be stressed is the necessity of using the lanyard in hooking and releasing so that the hands are kept clear of the block. In addition to the danger of fingers being caught between the hook and the ring, there is the danger of a hand being mauled between the heavy block and the boat as a swell raises the boat unexpectedly. In hooking on, always lead the lanyard through the hoisting ring and then use the lanyard to draw the ring on the hook. The hook should then be held closed by means of the lanyard until the boat is clear of the water and the weight of the boat is on the hook. To prevent the hook from accidentally tripping, the lanyard should be bent around the shank of the hook.

Hoisting In. Assuming that the boat is approaching the side of the ship to be hoisted in, all preparations should be made in advance for receiving it. The davits should be swung out over the side at right angles, and the blocks should be lowered near the water from the davits, crane, or boom. The sea painter should be dropped by means of a light line. The most important point is to be sure that the painter is secured to the boat at the proper time.

When in position the boat coxswain should order his men to hook on the blocks. When this has been accomplished, he reports this to the man in charge of the "hoisting in detail." The man in charge must not commence hoisting until it is reported by the coxswain that the blocks are hooked.

When all is in readiness for hoisting, the man in charge gives the command "set taut." The men on each winch then take the slack out of the falls. Because it is often difficult for the winch men to tell when the slack is out of the falls, the order "heave around together" and then "avast heaving" is given when the slack is out and the falls are taut. When the slack is out, the proceedings are stopped, and the man in charge checks to see that all is in readiness for hoisting, i.e., there are no dips or turns in the falls. When everything is ready, he gives the order "heave around together." If one end of the boat is hoisted faster than the other, the command is given, "avast heaving forward (aft)"; then "heave around together" when the boat is again level.

If possible the boat is stopped at deck level to disembark the personnel. When the boat has been hoisted high enough to clear the rail, the order is given "avast heaving," then "pass the stopper." When stoppers are passed and secure, the tension on the hauling part of the falls is eased off by the command "walk back together," at which the men on the winches slack the falls by rotating the turns around the gypsy heads. When the stoppers have taken the strain, the command "up behind and belay" is given. On this command the men at the winches throw off the turns and quickly take the slack to the cleats where it is belayed. Speed is essential, for at this time the weight of the boat rests entirely on the stoppers. When the falls are belayed, the stoppers are removed and the boat swung in.

13.2. Lowering and Hoisting Boats by Crane or Boom. A lee is first made and it is preferable in this case to have no way on the ship. Steadying lines are secured to the bow and stern of the boat and are tended by the boat

handling detail on deck. The safety runner is also rigged. The boat is then lowered until just clear of the water, and at the proper moment lowered quickly into the water. As soon as the boat is waterborne, the ring of the slings is run clear of the hook by a pull on the safety runner. Figure 13.4 illustrates the use of this safety runner. When the ship is rolling or pitching, steadying lines should be used on the crane blocks. The boat's engine should be running before

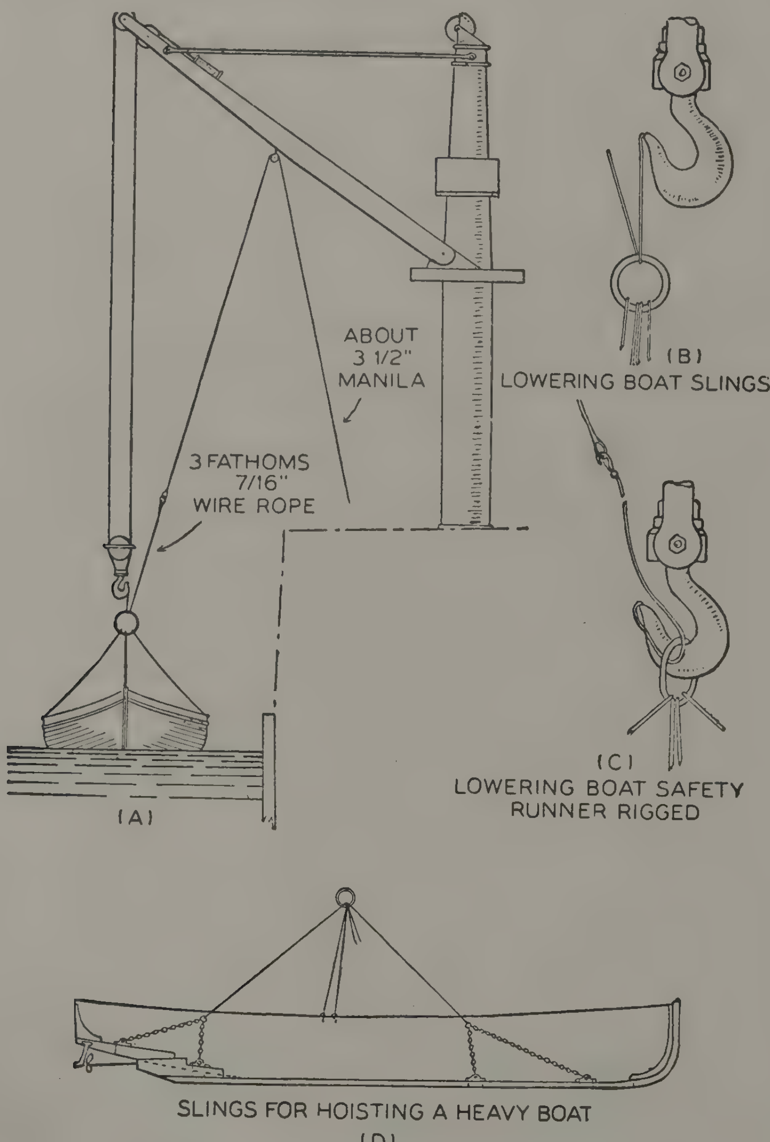


FIG. 13.4 SAFETY RUNNER IN USE WITH BOAT SLING

the boat takes the water. Round fenders should be hung over the bow and quarter of the boat.

When all preparations have been made, for hoisting, including handling the slings from the bight of the safety runner, the boat is worked up under the

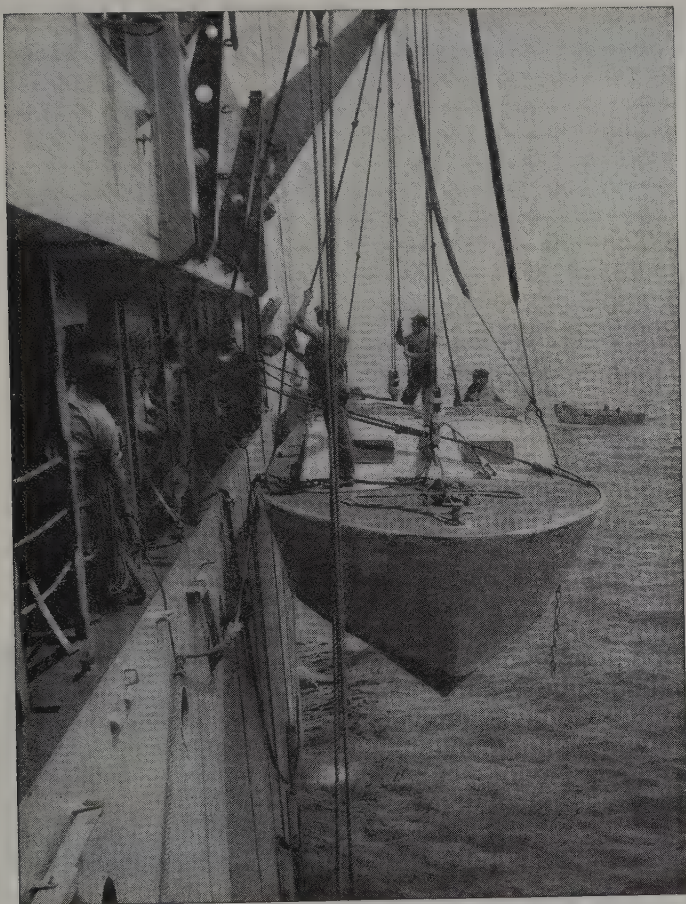


FIG. 13.5 MOTORBOAT HOISTED ABOARD USING A GRAVITY DAVIT. *Official U.S. Navy Photograph*

crane. The bowline, stern line, and steadying lines are passed, and the crane block lowered. The slings hang slack in the bight of the runner while the legs are shackled to the hoisting chain bridle of the boat.

When hoisting in a seaway using a crane or boom, there are three principal difficulties to be overcome.

First, after hooking on and hoisting has commenced, the boat may retouch the water, as the ship rolls, with a violent jerk which may prove destructive to hoisting gear. To avoid this, advantage is taken of a quiet moment. When the ship has begun to roll toward the boat or the boat is on the crest of a wave,

the block is quickly lowered, the ring of the slings is run onto the hook by the safety runner, and hoisting is commenced.

Second, the rolling of the ship may cause the boat to swing into the side of the ship as it is being hoisted. This danger is met by the use of fenders hung over the side of the boat. By properly tending the steadying lines, taking in and holding the slack as necessary, the swing will be somewhat reduced. The action of the steadying lines is similar to that of frapping lines. Where the boat is making headway through the water or the ship is pitching badly, a long bowline and stern line should be used to help reduce the surge fore and aft as the boat is being hoisted.

Third, after hoisting and swinging in, difficulty is sometimes encountered in plumbing the boat into the chocks. It is advantageous, especially where the boats stow close to the side of the ship, to have four steadying lines, two forward and two aft. These lines should lead from opposite sides of the boat at the bow and stern so as to cross each other, thus providing a better lead for steadying the boat into position.

Figure 13.5 shows a motor boat being hoisted aboard using a gravity davit. With this type of davit, the problem of plumbing the boat directly into its chocks is eliminated. Many other problems encountered when using either cranes or booms are also eliminated when using this type of davit.

13.3. Use of the Sea Painter. The sea painter is made fast close to the center to the forward thwart and leads out over the gunwale on the inboard side of the boat. It is rigged so to facilitate sheering the boat off from the side

FIG. 13.6 26-FOOT COAST GUARD SURFBOAT USED AS A LIFEBOAT ABOARD LARGE CUTTERS AND FOR TRAINING UNDER OARS. *Official U.S. Coast Guard Photograph*

of the ship when it is necessary to get away. On many occasions it is necessary to hold the boat alongside the ship in order to embark additional personnel. Many seamen recommend that a lanyard be attached to a bow shackle or ring at the stem which can be passed around the painter and then hauled tight to facilitate holding the boat alongside during this operation.

13.4. Handling a Power Boat. A Navy power boat crew usually consists of a *coxswain*, a *boat engineer*, a *bow hook*, and a *stern hook*. The coxswain is in command of the boat, subject to the supervision of any regularly assigned boat officer, or the senior line officer present in the boat. The engineer operates and cares for the engine. The bow hook handles forward lines and falls when making fast or letting go and acts as forward lookout when under way. The stern hook handles the stern lines and falls and keeps an eye out aft when under way.

In some boats the coxswain operates the engine himself. The clutch lever, the throttle, and the wheel are situated so that the coxswain can operate all of them. In the motor whaleboat and in others, however, the engine is located amidships, while the coxswain is stationed aft at the tiller. In this type of craft the boat engineer operates the engine according to bell signals received from the coxswain.

Word of mouth engine orders are never given in a power boat. The noise from the engine would normally distort or drown out completely all voice orders. A system of bell signals has been devised as follows:

Number of strokes	*Meaning*
1	Ahead slow speed.
2	Engine running, propeller shaft disengaged. When engine is not running, two strokes mean, "Start the engine." When engine is running with shaft engaged, two strokes mean, "Throw out the clutch to disengage the shaft."
3	Back slow speed.
4	Full speed in direction propeller is turning at the time the signal is given.

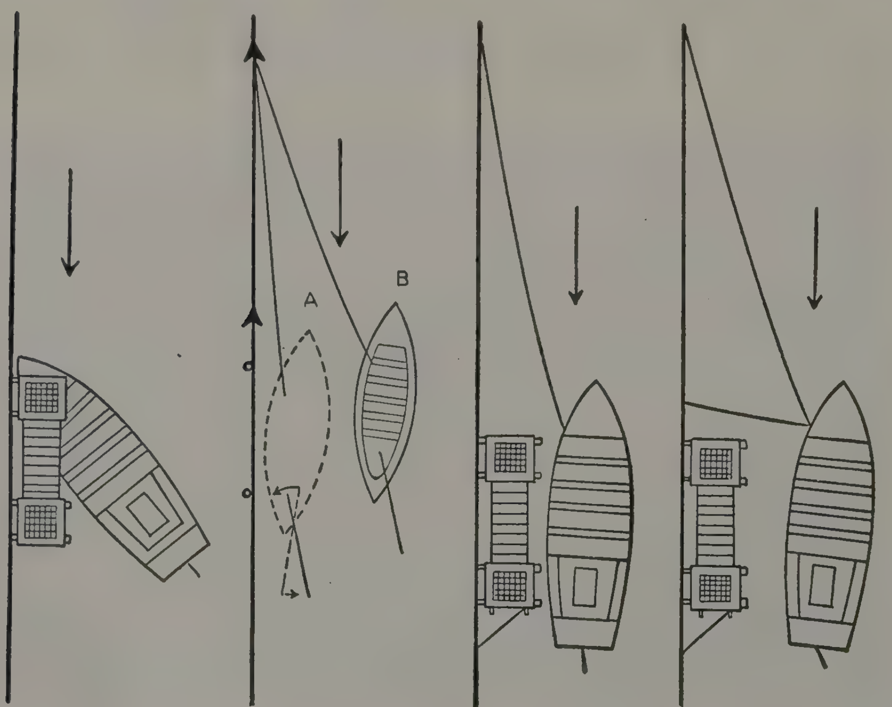
13.5. Handling a Power Boat Underway. Steering a power boat is much the same as handling a single-screw ship, although the reactions of the boat to the engines and rudder are more pronounced. When under way in choppy seas, speed should be reduced somewhat, not only to avoid shipping seas, but also to reduce the strain on the hull and on the machinery due to the racing of the screw when the stern rides clear of the water. Boats may be swamped by running them too fast against the seas. When heading into the sea, it is possible to make fair speed by careful nursing, i.e., watching the seas and slowing, or even stopping for a moment as heavier seas bear down upon the boat. As in ships, the boat sometimes may be made to ride much easier when, instead of plunging head-on into the sea or running directly before it, a course is made with the sea on the bow or quarter. If running more or less across the sea, it is well to head up momentarily to meet heavy waves.

A large motor launch or landing craft has a high bow, and turning against

the wind and sea is difficult. A large turning circle therefore may be expected and should be allowed for in confined waters.

Attention should be paid to weight distribution, especially in a head sea. Too much weight forward may cause the bow of the boat to plunge into the waves and possibly swamp; too much aft will cause the boat to fall off. When running before a heavy sea, weights aft will reduce yawing, but too much weight aft will cause the bow to ride too high. Wind and current should be observed and allowed for when leaving the ship or landing, as well as the compass course and time to destination, in order that the proper course may be steered in reduced visibility. In approaching any object in the water which may be damaged or injured by contact, such as a seaplane or target drone, always maneuver for a position that, when stopped, the boat and the object will be separating. A coxswain should be careful to slow in passing small open craft, men working on floats, or divers and swimmers, so as not to give them his wash. Neglect to do this can often prove dangerous to the other personnel near or in the water. Never pass a pier head, a bow, or stern of an anchored ship too closely.

13.6. Making a Landing. In making a landing, whether at a pier or a ship's accommodation ladder, it is a common mistake to keep too much way on the



(a) (b) (c) (d)

FIG. 13.7 LANDINGS. ACTION OF SEA PAINTER

boat (conditions of load and trim materially affect momentum). The landing should be approached at such an angle and at such a speed that, should the engine fail to back, control of the boat is still maintained and it can be sheered away by rudder action alone without damage. The engines may, and often do, fail to respond promptly. The backing throws the stern off to port

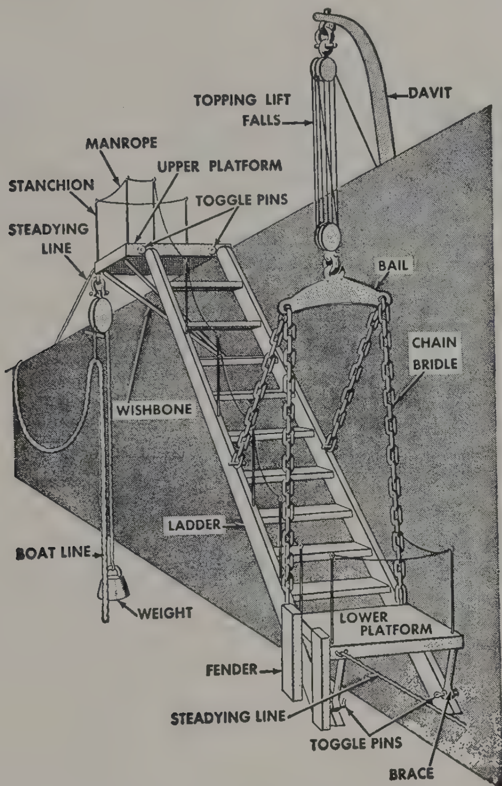


FIG. 13.8 ACCOMMODATION LADDER

(in a right-handed screw) which should be taken into consideration when determining the angle of approach. In coming alongside a ship's accommodation ladder in a current or in a heavy sea, care must be taken not to catch the tide or sea on the outboard bow, as this will sweep the bow in forward and perhaps underneath the lower platform of the accommodation ladder. Under these circumstances the boat may be swamped or damaged (Fig. 13.7a). The landing should be made by the aid of a boat line from forward, the boat being kept off a little from the side until the line is fast and then eased in by the rudder.

A power boat coming alongside in a rough sea or in a strong tideway should always be required to take a boat line. Crews of power boats frequently make their landings at an accommodation ladder by the aid of boat hooks alone.

This is done by taking hold of anything that is within reach, and holding on, often with great difficulty and with the ever-present danger of a man falling overboard between the ship and the boat. A boat, lying at the accommodation ladder in a tideway and secured by a boat line made fast to a cleat on the inboard bow of the boat, can be controlled by a touch of the rudder, which sheers the stern out or in and thus catches the current on one bow or the other (Fig. 13.7b). Where a ship is rolling in an open roadstead or riding with the wind ahead with waves surging aft alongside the ship, the boat rises and falls dangerously at the lower platform and contact with it may damage or capsize the boat. The need of a long boat line, in effect a sea painter, is here emphasized. By using the boat line in combination with the breast line and by judicious use of rudder and engines, the boat may lie alongside the accommodation ladder without coming into contact with it (Figs. 13.7c and d). Fenders should always be carried and used freely. See Fig. 13.8 for a rigged accommodation ladder.

13.7. Embarking and Disembarking. It is sometimes impossible, because of heavy seas, to make a landing at the accommodation ladder. In this case the passengers may come in over the boat boom. The rudder of the ship is put over to one side or the other, preferably to the side opposite that of the anchor. The ship will yaw back and forth but will usually yaw more on the side away from the rudder, thus creating a partial lee under her quarter. During each weather yaw of the ship, the boat pulls up under the quarter by means of a long bowline previously rigged and boat passengers can climb up cargo nets hung for this purpose from the boat boom or from the ship's side. As the ship yaws back, the boat drops back on the painter and awaits the next lee. Oil may be spread easily from the bow of the ship.

Another method of embarking is by a cargo net rigged under a crane or boom. As the boat comes under the crane or boom, the net is lowered and seized by the passenger, who is then swung aboard. When the ship is so equipped, the aeroplane whip of a crane with its fast hoisting speed should be used. This method is applicable under way in a heavy sea. It should be used only as a last resort, however, because timing must be precise and great danger is always present to the disembarking passengers.

The cargo net is also used in the embarkation of a large number of persons or troops at sea from the ship to a number of boats or landing craft. Cargo nets of sufficient length are hung over the side to reach into the boats. The boat comes alongside and is held there, while the foot of the cargo net is hauled into the boat and kept there while troops or personnel embark. The men who are already hanging on the net then drop into the boat.

Personnel may in like manner be transferred from the boat to the ship, but care must be taken in a heavy sea that the foot of the cargo net is taken into the boat to prevent personnel from falling between the boat and the ship and being crushed.

In the event of an emergency, such as recovering a number of people strug-

gling in the water, cargo nets hung over the side of the ship may expedite their recovery.

13.8. Securing Boats. Boats are usually secured to boat booms (Fig. 13.9), bows to guess warps, and sterns to a boat securing line which leads from the end of the boom well aft to the ship's side. This assists in holding the boats apart and in keeping them parallel to the ship. Sufficient slack should be allowed for roll and pitch when securing the boats.

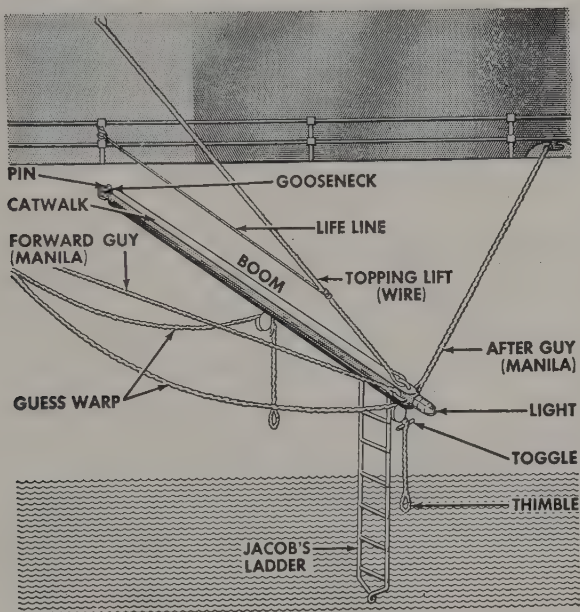


FIG. 13.9 BOAT BOOM

In a heavy sea or storm, the boat boom may become unstable due to the roll and pitch of the ship, making it impractical to secure boats to it. The boats may, in this situation, be secured in tandem from astern for the duration of the blow. In either event, always use fenders and take precautions against lines chafing.

13.9. Handling a Boat under Oars. A boat under oars, if properly handled, possesses much the same maneuverability as a power boat and, in the case of the whaleboat, considerably more seaworthiness. The following commands apply when handling a boat under oars:

Command	*Meaning*
Stand by the oars	Lift oars off the thwarts, place blades flat on the forward gunwales, push oars forward until handle is over respective thwart.
Up oars	Lift oars to vertical position. Trim blades fore and aft with handle resting on footings.
Shove off the bow	Bowman lets go boat rope or sea painter or hauls in boat painter. Shoves off bow using boat hook.

Command	*Meaning*
Let fall	Let oars fall into rowlocks using crook of outboard arm to control the oars. Trim oars horizontally with blades trimmed fore and aft. Bowmen up oars before command of "let fall" or put out oars as soon thereafter as possible.
Give way	Move blades of oars forward and dip about half way into the water and start stroke. At end of stroke, blades are feathered fore and aft and pushed forward and another stroke is made.
Oars	Complete the stroke and level the oars horizontally with the blades trimmed fore and aft.
Back water	Row backwards.
Hold water	Complete the stroke, stop rowing, dip blade about half way into water and hold water to stop the way on the boat.
Stern all	When rowing in ahead motion, complete the stroke, then commence to back-water, gradually increasing the depth of immersion of the blades.
Way enough	When rowing in ahead motion, complete the stroke, raise oars with crook of elbow to about 30 degrees, swing blades forward and place oars in the boat.
Toss oars	Complete the stroke, come to "oars," raise the oars smartly to the vertical, rest handles on the footings and trim blades fore and aft.
In bows	The bowmen complete the stroke, swing their oars forward and boat the oars, then stand by with boat hooks or to receive the sea painter or boat rope.
Boat the oars	From "oars" or from "toss oars," place the oars in the boat with blades forward.
Out oars	Place oars in rowlocks directly from the boated position or from "stand by oars" position.
Stand by to give way	Term used in racing. The blades are pushed to forward position and slightly dipped ready for an instant start.
Give way port, back-water starboard (or vice versa)	The orders are followed to turn the boat without making way ahead or astern.
Give way port, hold water starboard (or vice versa)	This command will result in turning the boat with slight headway.
Trail oars	At this command, the blades of the oars are brought alongside the boat and left trailing in the water, in single-banked boats fitted with swivel rowlocks.

Large boats propelled by oars, such as the whaleboat, are normally steered by a sweep oar. A sweep oar is somewhat larger than an oar used to propel the boat. The coxswain using this oar can steer the boat with a great deal more maneuverability than the standard tiller, dependent on how much leverage is used or how deep the oar is set.

Boats under oars may also be steered by the use of a tiller (rudder); however, except for use in extremely heavy seas or during long periods of time, the tiller possesses no advantages over the sweep oar nor is it as efficient.

13.10. Handling a Boat under Sail. It is beyond the scope of this book to describe the handling of the numerous yachts, pleasure craft, and small commercial vessels which use sail as motive power. Ship's boats are work boats. They are not designed to sail and none carry sails except incidentally. Reasons of stowage forbid the use of false keels and special ballast. Because of this, ship's boats must depend upon their beam for stability and always have a tendency to make much leeway. An attempt will be made to give an elementary explanation of the principles of handling boats under sail with the hope that it will be sufficient for use in an emergency.

13.11. Terms Used. The direction of the wind is that from which it blows. To *windward* is into the wind; to *leeward* is down the wind. A *lee shore* is the shore to leeward. The *weather side* is that side exposed to the wind; the *lee side* is the opposite side. Naturally a boat heels away from the wind, so that the lee side is *down* and the weather side *up*. When the rudder is amidships the tiller or helm [1] is also. The coxswain may put his tiller up to windward and have *weather helm,* or if he puts it down he has *lee helm*. When a boat turns her head into the wind, as if she were going to tack, she is said to *luff*. The opposite of this is *bearing away*.

When sailing with the wind on one side, a puff of wind may strike the sail, causing the boat to heel and possibly capsize. To prevent this, the coxswain may luff by putting his helm down until she turns into the wind; the sails then cease to *draw,* and the boat comes back to an upright position.

It may be necessary in a heavy squall to let the sheets go; therefore, in a small boat *never belay the sheets.*

When a sheet is hauled in and the boom or foot of the sail is nearly fore and aft, the sheets are said to be *hauled aft*. In *setting the jib aback* or *backing the foresail,* the weather sheets are *flattened aft*. This may be required to give more turning effect in tacking and is also done in *heaving to*. To bring the sails more nearly parallel to the centerline of the boat they are *trimmed in;* the opposite is *easing off* or *starting the sheets*.

A boat cannot sail directly into the *eye of the wind,* but, depending on the boat and rig, sails at an angle of from four to six points from it. She must thus make a zigzag course upwind on *tacks,* or *boards*. This process is called *beating to windward*. She is said to be sailing *close-hauled* or *on the wind* on each of these tacks.

A sailboat is said to be on the *starboard tack* when the wind is coming over the starboard side, and the *port tack* when the wind is coming over the port side. When a boat is not sailing as close to the wind as possible with advantage, she is said to be *sailing free*. When the true wind is within two points on either quarter, she is said to be *running* before the wind. If, when sailing free, the wind is still forward of the beam, she is said to be on a *close reach;* if the wind is from abaft the beam, she is said to be on a *broad reach*. The *apparent wind* is the wind striking the sails which is generated by a combination of the ship's speed through the water and the *true wind*. In obeying the Rules of the Road the prevailing or true wind fixes the respective obligations of sailing vessels.

Tacking is bringing the boat on the opposite tack, head through the wind. *Wearing* consists in turning the boat from one tack to the other tack, stern through the wind. During this procedure, as the wind comes aft and the sails are trimmed flat, the boom is carefully and intentionally allowed to swing to the opposite side. The boom is then said to have been *"jibed"* over. Should the

[1] While the terms "helm" and "tiller" have been officially banned in connection with modern ships, they are still applicable to sailboats and will be used here in accordance with original practice.

boat be sailing free and alter her course so as to bring the wind on the opposite side, carrying the stern through the wind, she has been "jibed," such as "jibing around a buoy."

Trim. To do her best under sail, a boat must be trimmed in accordance with her build and rig. To effect this condition, the trim of the boat and sails must be altered, as necessary, to meet the varying conditions of sailing.

In sailing on the wind, a properly designed and trimmed boat should carry a slight weather helm; that is to say, she should have a slight tendency to come into the wind. If too much weight is carried forward, the boat trims by the head, the stern rises, offering less lateral resistance aft to the water. The bow being deeper, offers greater lateral resistance to the water, and in addition has the increased pressure of the bow wave on the bow. These forces form a couple tending to cause the boat to luff, which, to counteract, necessitates an excessive weather helm. Too much weight aft causes a corresponding tendency to fall off.

If the sails are too flat forward, lee helm is necessary to counteract the tendency to fall off; if too flat aft, weather helm is necessary.

In addition, as the boat heels, the forward component of the force of the wind on the sail acting on the center of effort is displaced to leeward of the keel line, which produces a leverage which tends to make the boat luff. This tendency is especially noticeable in a tall sloop rig, which endeavors to "*work out from under*" when struck by a sudden gust as she is making good headway close-hauled.

When running before the wind, weights should be carried aft to decrease yawing, but this may decrease the speed, if overdone.

After the boat has been underway for some time, the sail or halyards may stretch, or in wet weather, may shrink. This calls for appropriate setting up or slacking off on the halyards to correct the set of the sail.

13.12. Close-hauled—on the Wind. On the wind, a boat should carry a little weather helm. The sails should be kept well full, sheets not too flat, but everything drawing and the boat alive. It is a common mistake to get the sheets so flat that the boat, while pointing high, actually makes a course to leeward of that which she would make if kept away a little with sheets eased accordingly; and it is of course clear that, if kept away, her speed will be greater than when jammed up into the wind in the hope of stealing a fraction of a point. A boat of good draft with a deep keel and centerboard, and yachts designed for racing, with fin-keels 10 feet below their normal water line, will lie amazingly close to the wind with little leeway. Ship's boats, however, are not constructed on yachting lines and cannot be held up in the same way. The shape of the sail when close-hauled is very important; the leech should be almost flat, and some boats, to accomplish this, have battens which fit in pockets in the leech of the sail. A little curve or belly should be allowed in the luff. The cut of the sails, the way they are laced to the yards and booms, and the tautness of the halyards all affect the shape of the sails when drawing.

The sails being properly set, the luff of the sails is kept just short of trem-

bling, with weather helm enough to let the helmsman "feel" that she wants to come into the wind. As the wind will vary more or less (in apparent, if not real, direction), it is necessary to be watchful and bring her up or keep her away from time to time in order that she may be always at her best. The sails should be kept fuller in rough than smooth water, as it is more important that the boat should be kept *going* so as to be always under command of the rudder. If a heavy breaking sea is seen bearing down upon her, she should be luffed to meet it and kept away again as soon as it has passed. If she loses way she becomes helpless at once. It is dangerous to be caught by a heavy sea on the beam; and, if the course to be made in rough water would bring the boat into the trough, it is the best plan to run off for a time with the sea on the quarter, then bring her up with it on the bow, and so make good the course desired without actually steering it at any time.

For a moderate squall, the boat should be luffed sufficiently to shake the sails without spilling them, thus keeping enough headway to retain control. If the wind becomes stronger, she must be luffed more decidedly and the sheets eased off. The sheets may, of course, be let go, and in an emergency this must be done at once, in addition to putting down the helm. For this reason it is a universal rule in boat sailing that the sheets should never be belayed or left untended in any weather.

13.13. Sailing Free. A boat sails her fastest on this point of sailing. The tendency to luff is strong, especially if the wind is fresh and the boat or sails are improperly trimmed. In a squall the situation is quite different from that in sailing close-hauled. Here the wind cannot be spilled by a touch of the tiller and the only prudent thing to do is to slack the sheets while luffing. In this procedure care must be taken not to jam the helm down hard for it causes the boat to heel dangerously to leeward, and as it turns into the wind the lee quarter and rail may go under, the end of the boom trip in the water, and the boat capsize.

The same thing may happen in jibing if the boat is allowed to fill away too quickly on the new tack. The force of the wind would be much reduced by running off, but the trouble with this is that, if it comes too strong, there is no recourse but to lower the sail, and the chances are that it will bind against the shrouds and refuse to come down. Moreover, there is always danger that the wind will shift in the squall, and the mainsail may jibe with dangerous force.

The gaff-headed rig has the advantage over the tall triangular rig on this point of sailing, but the gaff-headed mainsail must be tended more carefully, as the efficient angle to the apparent wind exists within narrower limits than that of the jib-headed rig. In general, in sailing free the gaff-headed rig must be trimmed closer than a jib-headed rig in order to maintain its most efficient angle. This requires close watching of the apparent wind at all times. Underwater resistance may be somewhat reduced by partially raising the centerboard, if the boat be so equipped.

The tall jib-headed rig gains power as the wind hauls forward and the low gaff-headed rig gains power as the wind draws aft.

13.14. Running before the Wind. In a fresh breeze, this is the most dangerous point of sailing, because of the chance of an unintentional jibe. The danger increases if the boat yaws. From this follows the rule to keep the weight fairly well aft, though never at the extreme after end when running before the wind. Very careful steering is required; and, if the sea is heavy, the boom may jibe in spite of all the care that can be tken unless lashed to the lee rail or shroud by a "lazy guy."

Squalls are not as dangerous before the wind as when close-hauled or reaching, unless they are accompanied by a shift of wind. To reduce sail quickly in a gaff-headed boat, to meet this emergency, the peak of the mainsail may be dropped.

In running before the wind, the foresail is sometimes set on the side opposite the mainsail, a temporary boom being rigged by using a boat hook or an oar. A boat sailing in this way is sailing "wing and wing."

If the sea is rough, it is well to avoid running with the wind dead aft. To make a course directly to leeward, the wind may be brought first on one quarter and then on the other, the mainsail being clewed up or the peak dropped each time the course is changed, if the breeze is strong enough to make jibing dangerous.

A serious danger in running before a heavy sea is that of "broaching to." The boat will yaw considerably, the rudder will be often out of water, and the sails will be becalmed in the trough of the sea. The situation here is much like that of a boat running in a surf; and, as in that case, the yawing will be reduced by keeping the weights aft and by steering with an oar. The jib should always be set with the sheet flat aft. It helps to meet and pay her off if she flies to, against the helm. A drag towed over the stern is also helpful.

Another danger in running is that the boom may dip as she rolls and thus capsize the boat.

13.15. Tacking. In tacking, the same principles apply to a boat as to a ship. An after sail tends to bring her head into the wind and a headsail to keep her off; but all sails, so long as they draw, give her headway and so add to the steering power of the rudder.

It is clear that a short full boat will turn to windward better than a long and narrow one and will require a much shorter distance for coming around. Thus a short boat is preferable to a long one for working up a narrow channel.

When about to tack, the coxswain should let her fall off a little to fill the sails and gain good headway, and he should watch for smooth water and avoid luffing into a breaking wave. The rudder should not be suddenly put hard over, but should be put over enough to have a good effect at first and then more and more as the boat swings; by the time the boat is swinging rapidly the rudder should be over about 30 or 35 degrees and held there.

Under ideal conditions, a boat, close-hauled but with good way on, shoots into the wind as the tiller is eased down, making a good reach to windward and filling away on the new tack, without a moment losing headway. The main

boom is hauled amidships in a two-masted boat and nearly amidships in a single-masted boat, and, as the jib and the foresail lift, their sheets are let go. The boat comes head to wind and as she pays off on the new tack the sheets are hauled aft and she is steadied on her course. Under less favorable conditions, such as a heavy head sea or a very light breeze, tacking is not so simple.

If the boat gets in "irons," the jib sheet must be held out on the old lee bow to pay her head around. Care must be taken not to make a "back sail" of the mainsail. If she gathers sternboard, the rudder is shifted, and, if necessary, an oar is gotten out to help her around. The statement is sometimes made that it is lubberly to use an oar in a boat under sail. The lubberly part is the getting into a position where an oar is needed.

Carrying the weights forward is favorable for tacking, but when a boat has sternboard she may be helped around by putting a few of the crew on the (new) lee quarter, where, by increasing the immersion of the full lines of the counter, they may add to the resistance and cause the bow to fall off.

Attention may again be called to the fact that in squally weather a boat is in a dangerous position whenever she is without headway, because she can neither be luffed nor kept away in the event of being struck by a heavy gust. If, through ignorance or carelessness, the sheets are belayed at such a time, the danger is greatly increased.

13.16. Wearing. In beating to windward, boats ordinarily go about by tacking, because in tacking they turn into the wind and gain ground to windward. In wearing around they turn away from the wind, losing more or less distance to leeward according to circumstances; still it is often possible to wear in winds so strong or water so rough that tacking ship's boats is impossible. It is often necessary to resort to wearing when maneuvering in close quarters, such as clearing a dock or avoiding a collision.

In wearing, the helm is put up and the mainsheet eased off in order to help in bearing away and to get the maximum effect of the mainsail in increasing headway. When the wind comes nearly aft the sheets are rounded in smartly in such a manner that both the sail and the stern pass through the wind at the same time. As the sails jibe over, the sheets are eased off slowly and gradually. Care should be taken at this point, especially with a sloop rig, that the boat be not allowed to come up on the new tack too quickly, as this may bring about a dangerous heel to leeward.

The details of the maneuver may vary considerably, according to the conditions of wind and sea and peculiarities of the boat as to rig and trim. In boats of more than one mast, it is best to sail dead before the wind, trim in the sails, jibe them, and ease them out on the new tack in the order of jib, foresail and mainsail.

In a fresh breeze, as jibing is dangerous, the mainsail should be doused, brailed up or the peak dropped before the wind comes aft, and set again in time to bring her to the wind on the new tack.

13.17. Remarks on Jibing. A sail is "jibed" when it is allowed to swing from one side to the other, the wind being aft or nearly so, and the sail full first on one side and then on the other. This may be done intentionally, as in wearing or in simply changing course, or it may come unexpectedly from a shift of wind or from the yawing of the boat. As it necessarily involves a violent swing of the sail, it puts a heavy strain upon the spars and rigging; it endangers everyone in its path and causes the boat to lurch more or less steeply to leeward. At this point the boat shows a strong tendency to luff on the new tack, and if not met with the rudder the boat may be knocked down and capsized.

It is important in jibing that the sails be trimmed flat before the stern of the boat is brought into the wind, and after the boom has jibed over, the sheets should be started slowly and gradually. The trimming of the sheets should be so timed with the swinging boat that the helmsman does not have to check his swing and wait for the sails to be trimmed in nor should the boat be allowed to run with the sheets flat aft. In either case the boat loses speed, and loss of speed is loss of control.

13.18. Reefing. When an open boat begins to ship spray and water over the lee rail, it is time to reef. A boat that is decked over may run with her lee rail awash; but when an open boat heels her gunwale close to the surface of the water, it must be remembered that a fresher puff may bear the gunwale lower without warning, and that the moment it dips, the boat will almost certainly fill and capsize.

The details of reefing will depend upon the rig, but a few general rules may be laid down. The men should be stationed before beginning, and should all be required to remain seated. The boat is then luffed, but not to the point where steerageway and control are lost. One hand lowers the halyards of each sail as much as necessary, another hauls down on the luff and shifts the tack. The sheet is hauled in a little to let the men get hold of and gather the foot. The clew earing, followed by the points, are then passed, and the halyards manned. The sail is then hoisted and the sheets trimmed as the boat fills away on her course.

If the boat has more than one sail, it is a good plan to reef them one at a time.

Handling Boats in a Surf

The proper handling of boats in a surf is an art in itself, calling for special judgment and skill that can be acquired only by practical experience. Some groups of seamen, such as fishermen along the New Jersey coast and the U.S. Coast Guard, have every opportunity to acquire this skill through experience and, in addition, are equipped with boats specially designed for the purpose. They are thus often able to take boats successfully through a surf so dangerous that it would be disastrous for the ordinary boat handler.

Amphibious operations require landings to be made regularly on beaches

where more or less surf may be expected, and landing craft are designed especially for this work. In addition, their crews must be specifically trained for this type of work.

Due to the hazards of the sea any seaman is likely to find it necessary to take almost any kind of ship's boat or raft ashore through a surf. He may have a green or exhausted crew whose lives as well as his own depend on his performance; therefore it behooves each of us to learn all he can of the subject both by study and actual experience whenever opportunity offers.

A surf never looks as dangerous from seaward as it is, especially from a small boat. When there is any possibility of a surf, a beach should be approached with caution, and care should be taken to remain well outside the breakers until ready to make the attempt at running the surf. If there is any possibility of help from the shore, it should be awaited before running a heavy surf. If no help is available and it is necessary to run the surf unaided, two principles should be kept in mind. First, the boat *must* be kept end on to the surf to avoid broaching and capsizing. Second, the boat must be able to meet and resist the breakers to keep them from driving her toward the beach out of control or, in extreme cases, driving her under or throwing her end over end.

Methods of running the surf vary with the height of surf, type of beach, set of current, weather, type and trim of boat, gear available, and experience and condition of crew. The means and methods to be used must be decided after a consideration of these factors which by their nature preclude the statement of other than general principles. Although there are various methods for handling boats in a surf and accomplishing a landing successfully, only the one considered safest and simplest is discussed here.

13.19. Landing through a Surf. The most important consideration for the inexperienced coxswain is the necessity for remaining outside the breakers for a long enough time to study the surf carefully. Care must be exercised to ensure that the boat is kept far enough outside the outermost line of breakers to avoid being caught unexpectedly by a sea. When this is done, one will find that the large seas come in a more or less regular sequence, usually three or four in a series. Then follows a period of smaller seas during which there is a period of build-up. It is during this time that the entrance into the line of breakers must be made.

Having determined the period of the seas and decided on the run in, wait until the last sea of the large series breaks just inshore of the boat and then turn so as to present the bow seaward and back in. As each succeeding wave overtakes the boat, it may be necessary to pull ahead to meet it. With this method the oarsmen are normally faced so that the coxswain may best use them to control the speed and direction of the boat. Too much emphasis cannot be placed on the full utilization of the oars in steering the boat. It is possible for the boat to be kept headed directly into the seas by having first one side and then the other give way as may become necessary. As each sea passes, "stern all" and gain more distance toward the beach. With each overtaking

sea the boat will be carried shoreward a considerable distance, even though the oarsmen are pulling against it. If even the smaller seas are of dangerous size, it will be necessary to impart a great deal of way to the boat in order to give it sufficient inertia to overcome the power of the sea and avoid broaching.

Broaching is most apt to occur when the seaward end of the boat is lifted by an onrushing wave, depressing the shoreward end in the relatively calm, motionless water which is immediately in front of the wave. We have, under these circumstances, one end of the boat deeper than the other and embedded in stationary water while the other end has a tremendous force acting on it. It is apparent that this force applied to one side or the other of the seaward end of the boat will create a powerful turning moment, one arm of which is equal to about the length of the boat. Thus, it is obvious that a great amount of power is necessary to overcome the forces which tend to cause broaching.

Considering the weight of the boat constant, since buoyancy is also a paramount feature, this power can be met only by rowing strongly against each oncoming wave. Weights should be located in the bow (seaward end) of the boat, but not in the extreme end. Oarsmen should use a short, fast, powerful stroke so that they may back-water as each sea passes with as little delay as possible.

It should now appear that the seaward end of the boat is the most important and the one on which adverse forces are apt to be most dangerous. Hence, it follows that, if there were some means of holding the bow steady while the overtaking seas pass, the problem would be less difficult. In practice there are two very handy devices for accomplishing this. These are the *drogue* and the *surf-line*.

A drogue is a conical-shaped bag about 2 feet wide across the mouth and 4½ feet long. It is towed mouth foremost by a 2½-inch line which is secured to the mouth by means of a bridle. A small line known as the tripping line is made fast to the apex, or pointed end. When towed mouth foremost, the drogue fills with water and offers considerable resistance; when towed by means of the tripping line, the resistance becomes negligible and the drogue passes through the water easily.

When a drogue is used in a boat landing through a surf, it must be carefully tended by men in the bow so that there is always a strain on the towing line when a sea overtakes the boat. When the sea passes it is desirable to "stern all," and the tripping line is hauled taut so that the drogue passes easily through the water. The coxswain and men tending the drogue must be alert to slack the tripping line well in advance of the arrival of the next wave in order to allow it to fill with water and exert the greatest resistance to keep the bow pointed seaward. A drogue is especially recommended when there is any current setting parallel to the beach.

A surf-line consists of a 2½- or 3-inch line made fast to an anchor just beyond the outermost line of breakers. This line should be about 150 fathoms long. The line which is coiled in the boat free for running is payed out by men

in the bow so that there is always a strain on it when the boat is overtaken by a sea; as the sea passes, the line is again payed out.

A surf-line exerts a more positive force on the bow of a boat landing through a surf, but it is not recommended when there is any appreciable current setting parallel to the beach. The reason for this is, of course, that the farther the boat progresses (i.e., the longer the scope), the more it will be carried down by the current. Hence, there will actually come a time when the boat will be carried broadside to the waves or nearly so and be in grave danger of capsizing. Another disadvantage of the surf-line is that it actually stops the progress of the boat toward the beach each time the men in the bow hold it to permit a sea to pass under the boat.

13.20. Landing Craft (LCVP). The most interesting and important phase of LCVP operation is the run to the beach. In the surf, the coxswain and crew are really put to the test. There are a number of factors to be kept in mind when the student coxswain goes into the surf for the first time. These will be discussed, roughly, in the order in which they occur during a landing operation.

The coxswain should make certain that each crew member is in his place as he makes ready for the run. It is necessary that all men wear life jackets when the LCVP or LCM is launched. There may be no time to slip them on in an emergency. Even a champion swimmer can drown in a hurry if he happens to be knocked out for a moment in an accident, as when a boat turns over.

As the beach is approached, the rolling ground swell which begins to rise several hundred yards out from the shore determines the size of the surf. Once inside the breaker line, course should not be changed. Therefore, the boat should be lined up with the spot on the beach where it is to be landed. This should be done before the boat enters the surf.

The LCVP, handled by an expert, can cope with a 12-foot surf, but a 6- to 8-foot surf is high enough to cause plenty of trouble, especially for the beginner. Regulate the speed of the boat so that it rides in to the beach *just behind the crest of a comber.* If the boat is right on the crest it will be set down *hard* on the sand when the wave crashes and ebbs.

The boat should be kept *at right angles to the surf.* The LCVP is likely to broach if this rule is not observed. Usually the surf goes in parallel to the beach and if you hit the sand head-on the boat will ground safely.

The exact spot at which the coxswain aims his boat should be chosen with care. The LCVP was designed primarily to run aground on a sand beach. Any large stones or outcropping of rocks that might damage hull or ramp should be spotted in advance. Both coxswain and forward lookout will need to keep a sharp eye open for underwater obstacles.

If the boat should run aground on a sandbar some distance from the beach, the engine should be run slowly in forward speed until the hull is floated partly free by the next breaker. When the boat has this flotation, the engine speed

should be increased. If the boat is not freed, the engine speed should be cut and an attempt made when the next incoming wave lifts the boat.

It is unwise to assume that the water is shallow all the way to shore if the boat grounds some yards out. Unless word is received from the beach party, the unloading of troops should not be attempted. The water may be 10 feet deep a few yards inshore from a sandbar that has stalled the boat.

After clearing all bars, the LCVP should be run on the beach at a good speed to ensure a good hold on the sand. When properly beached, the boat is at right angles to the surf and its keel is grounded along its entire length. In this position the boat is not likely to broach while loading or discharging cargo.

FIG. 13.10 25-FOOT SELF-BAILING, SELF-RIGHTING SURFBOAT (NON-POWERED)

The engine should be kept turning over at about 1200 rpm's to hold the boat well up on the beach. Avoid letting the screw race wildly. Idle down when water recedes and the screw loses its bite between breakers.

Should the engine fail or some mishap occur when the boat is within the surf-line but not aground, the first thing to do is drop a stern anchor. This helps to hold the stern at right angles to the breakers if the line is payed out carefully. *Do not snub* the line, but let the boat surge toward the beach with each comber. Only when the boat touches the beach is the anchor line snubbed to prevent broaching. The flow of the tide is something to take into consideration if the boat will be beached for any length of time.

Several precautions may be taken to keep from broaching. *First,* be sure that the breaking seas are kept dead astern. Otherwise the stern will fall off to port or starboard as the water dashes against it. *Second,* drive well up on the beach so that the entire length of the keel is aground. *Third,* speed up engine in forward gear as incoming waves float the boat. *Fourth,* see that the antibroaching lines are thrown to the beach party at once. Figure 13.11 (a, b, c) show how these lines are used to prevent broaching.

No hard and fast rule can be laid down for the use of the antibroaching lines. The coxswain must think and act intelligently to allow for wind, different types of beaches, and other factors influencing broaching. Usually, however, it is wise to line up the bow with some object on the beach. Then it is immediately apparent if the bow or stern is moving. If this happens, the rudder should be put *in the direction in which the stern is swinging.* Then the engine should be speeded to drive higher on the beach to bring the stern around. Sometimes, if the surf is not high, it is possible to free the broached boat by engine power alone.

When retracting from the beach the coxswain tackles the most difficult part of the landing operation. It is during retraction that the beginner at boat handling is likely to broach or damage the rudder, screw, or skeg.

The coxswain will be most successful in getting away from the shore and safely beyond the breaker line if he observes the following:

1. The rudder should be set amidships before attempting to retract. In the LCVP this may be done by running the engine about half speed ahead. The discharge current or wash from the screw will force the rudder into an amidships position.

2. The bow should be lined up with an object on the beach. If this is done it will be easier to note any swing of the boat soon enough to correct the movement and hold her straight.

3. Next, the engine should be shifted into reverse and a wave to float the hull should be awaited. When flotation is achieved the engine should be accelerated. Nearly always the boat will move backward a short distance.

4. When the wave recedes the engine should be prevented from racing needlessly as the screw loses its bite in the water; this will prevent the rudder and skeg from digging into the sand upon which they rest.

5. If the bow begins to swing, the steering wheel should be turned *in the direction of the swing.* This should bring the bow back. The wheel should then be turned back before this return swing is completed or the bow will move too far and require more maneuvering.

6. Once the LCVP is floating free and has passed any outer sandbars, it should be backed at right angles to the surf until outside of the breaker line.

7. Once through the breakers, and when the boat is on the crest of a wave, the rudder should be put over hard, the engine shifted into forward, and accelerated. This will cause the boat to pivot quickly and take the next sea on the bow.

13.21. Beaching and Retracting with the LCM. Most of the general rules laid down for running in to the beach in the LCVP are observed when piloting the larger tank lighter. The boat is kept at right angles to the surf and is driven ashore just behind the crest of a wave. It should be grounded well up on the beach along the entire length of the keel and the engines kept running with enough speed to hold the boat firmly beached while loading or unloading.

Once the coxswain is familiar with his boat, the tank lighter is easier to

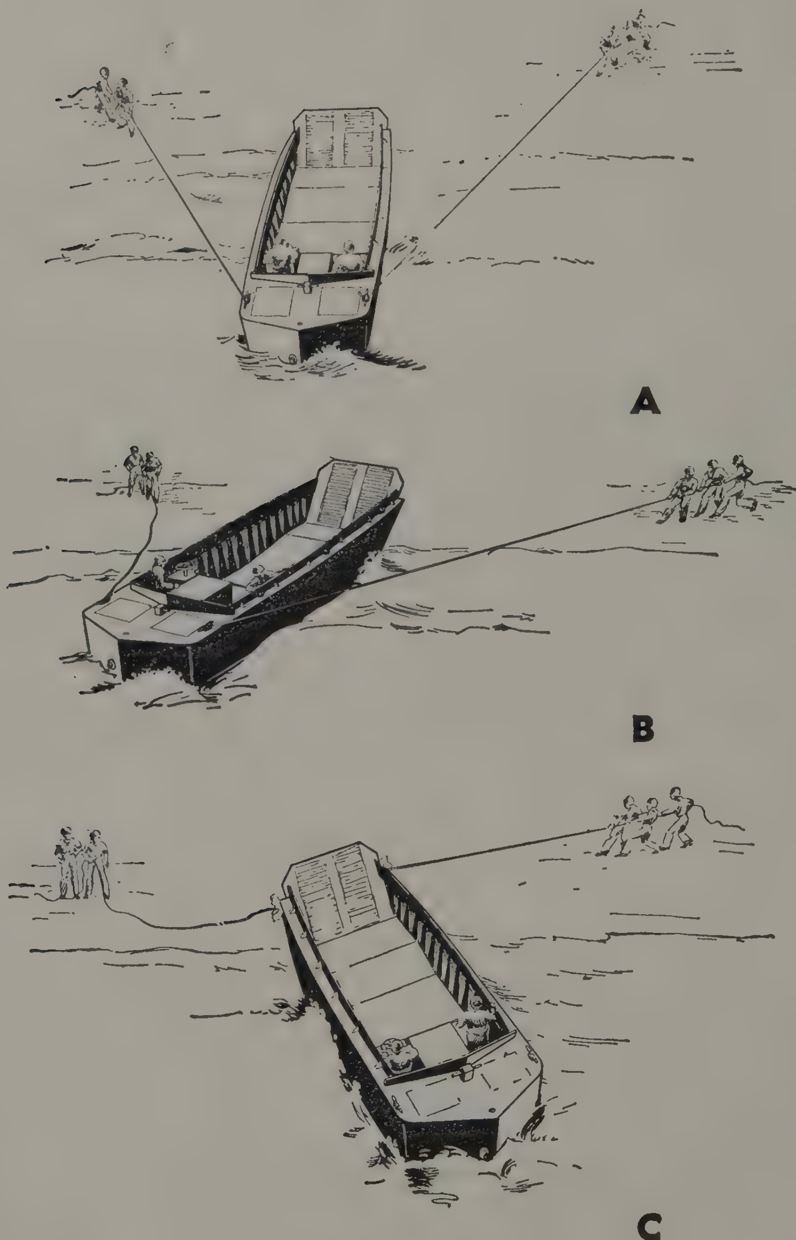


FIG. 13.11 BEACHING AN LCVP

retract than the smaller, single-screw LCVP. This is due to the fact that the twin-screw design gives better control over the bow's tendency to fall off to port or starboard when backing through the surf. In retracting, the LCM's rudders are put amidships, both engines are reversed, and she is backed off slowly.

If the bow falls off to starboard there is no need to spin the wheel. The coxswain simply speeds up the port engine in reverse until the swing is corrected. Ease off on the throttles, however, as soon as the bow begins to come back to starboard. Otherwise it might continue its swing and fall off to port.

Like the LCVP, the tank lighter can broach in a few seconds. Because of her

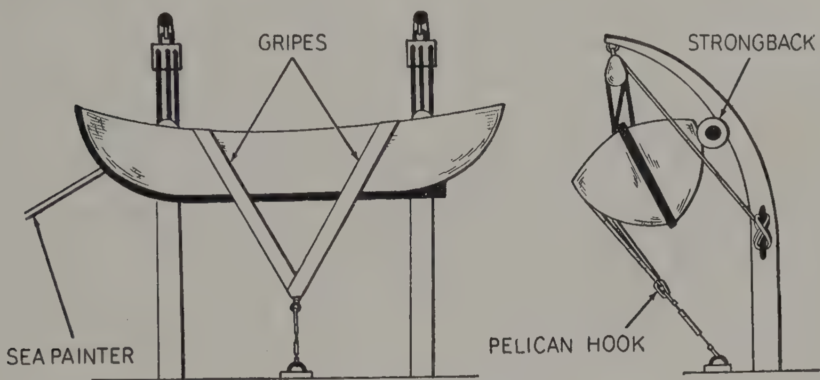


FIG. 13.12 READY LIFEBOAT

greater size, the LCM is apt to be more difficult to salvage. The same precautions to be followed with the LCVP help to keep the LCM at right angles to the surf.

13.22. The Motor Lifeboat. Prudent seamanship requires that a boat always be kept ready for immediate use as a lifeboat. Aboard all men-of-war and many passenger liners a boat of the motor whaleboat type is used as the ready lifeboat. The Coast Guard, however, to some extent uses the pulling whaleboat, but since the means of stowage and launching do not normally differ from the motored version, it will not be discussed separately.

Men-of-war, if so equipped, have two of their boats rigged as ready lifeboats, one on either side to expedite lowering. Smaller men-of-war and most auxiliaries have only one boat rigged as a lifeboat. Passenger liners like large men-of-war have two small boats rigged, normally situated on either side forward of the boat deck. The sea painter is kept rigged, and it becomes only a matter of releasing the gripes before the boat can be lowered. Most Navy lifeboats are rigged for lowering by radial davits as shown in Fig. 13.12, whereas most merchant ships use gravity davits. It must be pointed out that boats of the Merchant Marine are in themselves lifeboats and, as such, are rigged for immediate use. Thus, with but few exceptions all boats aboard

merchant ships may be used as ready lifeboats with no special preparations.

Since the gravity davit does not require that the boat be swung out to facilitate speed in launching, only the use of the radial davit will be discussed in any detail. As a general rule the davits are swung outboard and the boat is griped against a spar spanned between the davit arms called a *strongback* or *pudding spar*. The boat is griped up against two puddings (fenders) built up around the spar. The V-shaped grips (made of line or wire covered with canvas to prevent chafing) have their upper ends shackled to eyes in the strongback or pudding spar. The lower end of the V is attached to the deck, which is joined by means of a turnbuckle equipped with a pelican hook. The turnbuckle is used to take up any slack and keep the boat snug against the puddings. The pelican hook is used for quick release.

In order that the weight of the boat does not rest upon the falls, wire pendants called preventers are run from the davit heads to the hoisting eyes of the boat. These pendants are also equipped with pelican hooks to facilitate quick release. Aboard auxiliaries and merchant ships, the lifeboat generally rests upon chocks directly beneath the davit. To secure this boat for sea in its chocks, clamps equipped with a turnbuckle are used. The lower end is secured to the deck and the clamp is fitted over the gunwale. Several quick turns of the turnbuckle are all that is required to release the clamp and have the boat ready for instantaneous lowering.

Helicopter Operations

13.23. The Helicopter at Sea. The helicopter is of marked significance to mariners, performing a variety of useful or vital services in its capacity of a physical link between ships and between ship and shore. Some of the many tasks regularly performed offshore by helicopters are:

At-sea pickup and transport of emergency medical cases.
Search and rescue.
Transport of supplies and personnel.
Icefield reconnaissance.
Planeguard duty for navy aircraft carriers.
Anti-submarine search and attack.
Coast and Geodetic Survey support.
Minefield reconnaissance and minesweeping.

A responsible mariner will inform himself of helicopter capabilities, limitations and requirements, for he can expect to work closely with this unique tool at some stage, perhaps on short notice.

Life or health is frequently at stake in helicopter operations. Those awaiting help may be jeopardized by the failure, delay, or inefficiency of a helicopter mission. Participants or bystanders may be endangered by an accident, not necessarily a crash, during operations with a helicopter. Con-

sequently, knowledge of and adherence to prescribed operating and safety procedures, and the development of informed judgment are required of those working with or near helicopters.

13.24. Helicopter Types. In general configuration, the two most common types are the following.

Single rotor—having two or more large horizontal rotor blades rotating about a single vertical axis near the helicopter center of gravity. There is also a small vertical sidefacing propeller at the tail used to counteract the torque effects of the large rotor and to provide control about the yaw axis.

Tandem rotor—having two sets of horizontal blades. One set of blades (one rotor) is placed near each end of the fuselage. These rotors rotate in opposite directions thus no vertical anti-torque propeller is required.

Helicopters may be either single-engine or twin-engine. The transition from reciprocating engines to gas turbine engines in recent years has markedly improved helicopter performance.

13.25. Helicopter Characteristics. Helicopters perform many demanding tasks under difficult conditions. However, they are as vulnerable to misuse as any complex machine. Respect for their characteristic limitations is as important as proper use of their capabilities.

Lift for flight is achieved by the speed of rotation of the rotor, rather than the forward speed of the vehicle as in the conventional airplane. Consequently hovering, sidewards, and backwards flight are possible, within definite limits.

Helicopters are characterized by relatively slow airspeed. While top speeds well in excess of 100 knots can be reached by modern helicopters, many current and all older models cruise at speeds of 65 to 85 knots. The most frequent and critical helicopter operations take place at very slow speeds and low altitudes. These include takeoff and landing, hovering, and flight operations around a ship.

In case of failure of an engine in flight, a twin engine helicopter may be able to use the remaining good engine to continue flight or to make a powered landing. A single engine helicopter must land in the event of engine failure. However, under most flight conditions the helicopter can be brought to a controlled landing by the process of "autorotation." This is a maneuver in which the helicopter forward motion, descent, and proper pilot action cause the rotors to continue to turn, and so produce enough lift for "gliding" flight.

Modern helicopters of moderate to large size, particularly those operated by the U.S. Coast Guard and the U.S. Navy, are equipped for instrument flight, and can operate over water in weather of moderate severity. Older helicopters and the smaller models of current helicopters have very limited ability to operate at night over the water or under conditions of low visibility. Unless equipped with the proper instruments and radios for blind flying, the best helicopter pilot is running a great risk when he undertakes helicopter flight without a visible horizon.

The useful operating range of a specific helicopter is primarily influenced by the wind velocity and the rate of fuel consumption, which depends upon the engine power setting used. Range and endurance vary with specific helicopter models and the conditions under which the helicopter is operated. Sustained high speed flight or sustained hovering markedly reduce flight endurance because of high power settings. A typical endurance figure for normal flight conditions, however, would be about two to three hours, with another hour available in some cases by the use of auxiliary fuel tanks. Hovering, slow flight, and lateral flight are valuable helicopter characteristics. Sideward and backward flight are limited to a few knots airspeed, except that the tandem rotor helicopter can accomplish sideward flight of up to about 30 knots. A helicopter normally must hover facing into the wind since, with the wind abeam or wind aft, slow groundspeed or hovering is possible only in very light wind conditions.

In the hovering condition, the action of the rotors pushes air downwards to the surface. The air then flows outward and circulates back into the rotors from the top. This downwash has considerable velocity and its effects should be anticipated by those working with helicopters. For personnel working near or under a hovering helicopter on a deck, the wearing of helmet and goggles is advisable. Debris and loose articles of clothing are hazards in the vicinity of a hovering helicopter. Objects may be blown overboard or low density objects, such as hats, can be captured by the recirculating air pattern and pulled into the helicopter blades, causing damage. When hovering over the water, downwash blows spray at high velocity, which can reduce efficiency of personnel in a boat under or near the helicopter.

Many modern helicopters are amphibious, capable of landing in the water in light to moderate sea states. If some lift is being provided by the rotors, considerable waterborne stability is provided. Conversely, with no rotor lift waterborne stability is reduced. In this condition, if the helicopter rolls or pitches very much the tips of the rotor blades may touch the water.

For operations where landing is not possible or desirable, the helicopter normally will use a powered hoist, carrying 50 to 100 feet of strong, flexible steel cable. A hook at the free end of the cable permits the attachment of devices such as a net, basket, Stokes litter, light cargo in a bag, or a harness or sling for lifting a man into the helicopter. Some helicopters are rigged with external cargo hooks underneath, at the center of gravity, for the attachment of heavy cargo in cargo nets or on pallets in slings.

A common device for hoisting able personnel to and from the helicopter is a sling which attaches to the hoist cable hook. This is a loop of webbing, sometimes padded into a horsecollar shape. The bight of the loop should always be placed at the back of the man to be hoisted, with the ends passing under each arm up to the hook. A common and dangerous mistake occurs in placing the bight in front, over the chest.

FIG. 13.13 U.S. NAVY RESCUE/UTILITY HELICOPTER, MODEL UH-2A, TURBINE POWERED, BUILT BY KAMAN HELICOPTER CORP. NOTE RESCUE NET IN WATER

FIG. 13.14 U.S. MARINE CORPS CH-46A *SEA KNIGHT* HELICOPTER LANDING ON THE DECK OF THE *U.S.S. OKINAWA*. THE NAVY VERSION IS THE UH-46A. *Boeing Photo*

13.26. Wind. Wind velocity and turbulence are major factors in helicopter operations and must be taken into account at all times by the pilot and by shipboard personnel working with a helicopter. The presence or absence of relative wind can determine or limit the helicopter's ability to take-off or hover safely with a heavy load. This is particularly true in hot, humid weather which reduces helicopter performance as a result of the lessened atmospheric density.

A helicopter can fly in forward flight with somewhat more load than it can safely support in hovering flight, because of increased lift provided by the relative wind created by the helicopter's forward motion. In a practical sense, this means that under some conditions a helicopter is able to maintain station over the deck of a ship only if the ship maneuvers to provide the necessary relative wind velocity. With insufficient wind velocity, the helicopter may not be able to hover, or may operate with inadequate margin of safety to properly cope with turbulence or an emergency.

The relative wind with respect to the ship should, if possible, satisfy several conditions. Preferably it should provide a clear, overwater, upwind approach for the helicopter to the position at which the ship-helicopter operation, such as hoisting a man, will take place. To minimize turbulence, the wind should reach the helicopter after having passed around as little superstructure as possible. The wind direction should permit the helicopter to face into the wind, or nearly so, while maintaining its hover over the ship. This helicopter heading should permit a clear view of the ship by the pilot so that he can have adequate visual reference for accurately maintaining position over the deck. If a clear deck or level space exists aft for helicopter operation, it can be seen that these conditions are well satisfied by the ship taking an upwind course and speed which establishes the relative wind about 10 to 30 degrees on the port bow, with relative velocity of over 10 knots. The helicopter pilot, normally in the right hand seat, then has the ship in full view during approach and hover. If the helicopter must operate at a point other than the after end of the ship, a relative wind close to broad on the ship's beam is generally preferable, to permit a clear approach. In the case of a ship dead in the water less flexibility exists and the pilot must determine whether safe operations are possible.

When the helicopter is traveling point to point, wind direction affects performance and navigation. A helicopter cruising at 60 knots airspeed on a course directly into a 30 knot wind can achieve, at most, one half its no-wind range, and has a ground speed of only 30 knots. Any crosswind component reduces range, even for a round trip flight, because of the necessity to crab into the wind to maintain the desired track. Wind effects on helicopter ground speed must be kept in mind by controlling personnel of a ship from which a helicopter operates.

13.27. Emergency or Occasional Operations with Helicopter. The ship which does not regularly operate with a helicopter should nevertheless

anticipate the possibility and be prepared. The most probable occurrence will be the necessity to transfer an individual between the ship and an airborne helicopter by helicopter hoist. If a U.S. Coast Guard helicopter is involved, the ship can expect to be contacted on radio (HF, VHF, or UHF), and briefed by the pilot as to his intentions and requirements for ship actions. Such a brief set of instructions obviously is no substitute for previous indoctrination of ships' personnel. If the helicopter is unable to establish radio contact, the degree of urgency and pilot's discretion will determine whether or not a message drop, large writing on a blackboard, or other communication will permit enough information exchange for the personnel transfer or other mission to be safely accomplished. Fuel limitations may preclude time-consuming attempts to communicate at length by other than radio, or to engage in prolonged hovering over the ship. Consequently, ship action which immediately demonstrates familiarity with helicopter operations by steering a good course and by manning the appropriate deck area with properly equipped personnel saves valuable time and may make the difference between mission success and failure.

13.28. Sustained Operations with Helicopter. A ship which is to operate a helicopter from its deck should prepare, with the help of the helicopter pilot, a "Helicopter Operations Bill" which details stations and defines duties and responsibilities for various operations; including launch, land, refuel, and emergencies such as deck crash, fire, and man overboard. Explicit safety precautions should be part of the bill or issued as a separate directive for wider promulgation.

13.29. Safety Precautions. Implicit in the foregoing description of helicopter characteristics and limitations have been the basic precautions to be observed in operating with helicopters. Listed below are some specific procedures and precautions.

A. *Preparations for receiving helicopters for hovering transfer.*

1. A green flag prominently displayed at the landing or hovering area indicates that the ship is ready to receive the helicopter.
   A red flag means "do not make approach yet" or "discontinue approach."
2. Provide a clear deck, free of loose gear.
3. Remove or rig out of the way: stays, booms, whip antennae, loose halyards and other obstructions which may endanger the rotors in the hover position.
4. Clear from the vicinity all exposed idle personnel. High velocity blade fragments, in case of accident, can endanger bystanders.
5. Have lifeboat manned and, if possible, rigged out.
6. Have medical, fire, and rescue parties stationed.
7. If able personnel are to be transferred, have them in life jackets and briefed in procedure.

8. Have helicopter hoist detail properly trained, clothed, and equipped. A pair of bolt cutters should be readily available for emergency use.
9. If stretcher (Stokes litter) patient is to be transferred, have a light free-running tending line attached to one end of litter. This is hand-tended under very light tension to orient the litter. DO NOT SECURE LINE TO SHIP. Attach hoisting bridle to litter with the short lines at the head, so that head will ride high.
10. Under penalty of causing the helicopter to crash, NEVER attach helicopter hoist cable (or any line from helicopter) to ship, or allow it to become fouled. Should this inadvertently occur, notify pilot and cut cable *immediately* with bolt cutters or heavy cable cutters. The cable is tough stainless steel and will not yield to a light tool. The only exception to immediate cable cutting is the case where there is no doubt that pilot knows the situation and is able to hover low to keep slack in the cable until it is freed.
11. Do not attempt to hook on to the hoisting hook until slack exists in the hoist cable sufficient to accommodate unexpected relative motion between helicopter and the deck which can be caused by a pitching deck or by helicopter motion in turbulent air.
12. The helicopter should spend as little time over the deck as possible. When not actually performing hoist maneuvers, the pilot should normally move abeam to windward so as to avoid hitting the ship in case of loss of power.
13. Personnel who operate under the helicopter should be trained or briefed for maximum efficiency so as to minimize hover time and time spent under the helicopter.

B. *Launch, land, and on-deck operations:*

A ship operating a helicopter regularly will have detailed instructions available from the helicopter detachment. Some basic precautions are:

1. Caution in moving helicopters aboard ship, or in moving objects near the helicopter, is necessary to avoid damage. The helicopter is very vulnerable to collision and to thrown or falling objects (such as tools, or a baseball).
2. Due to possible existence of turbulent winds over the deck, and deck motion, the helicopter should always be checked and securely tied down on the deck, and if possible spotted facing into the wind.
3. Helicopters should not be fueled with engine running except in emergency.
4. Personnel should not be allowed to walk under rotors during rotor engagement or shutdown due to blade flapping at low rpm.
5. Personnel should never approach helicopter on deck while rotors are turning unless the plane director on deck and the pilot are aware of their presence and permission is granted to approach.

6. Only qualified personnel should be allowed around helicopters, particularly when operating.
7. Fire extinguisher bottles should be manned when starting and refueling engines.
8. Launch and recovery cannot be attempted safely while ship is in a turn.
9. Pilot is responsible for insuring that *all* tie downs are off before lifting the helicopter off. Failure to do so results in an almost certain crash.

C. *Joint rescue operations:*

When a helicopter and surface vessel (ship or boat) jointly engage in a rescue attempt of personnel in the water, maximum coordination is essential. Otherwise mutual interference can result to the detriment of those awaiting rescue, and with hazard to both the helicopter and surface vessel. In no event should competition be permitted to develop. The first to arrive at the exact site of rescue should normally be in charge of the operation. The superior speed and rescue capability of a trained helicopter team should be recognized in most instances. The helicopter and surface vessel may be able to perform rescues simultaneously, or the helicopter's superior search capability utilized. Alternatively, one or the other might better stand by, ready to render assistance, but remaining clear so as to provide ample maneuvering room to the other. When standing clear, the surface vessel should be aware of the helicopter requirement, normally, to make an upwind approach to a point of rescue and should avoid blocking the approach and take-off path.

14

Ice Seamanship

Maritime activity in the high latitudes, both on the surface and sub-surface, has become common and a mariner can find himself facing the problems of preparing his ship, cargo, and crew for operations under the most unusual and prolonged extremes of weather conditions that exist in the Arctic and Antarctic areas.

The annual resupply of the northern defense line of bases, support of the Arctic weather stations, submarine operations under the polar ice and the Antarctic activities require seamen knowledgeable in ice oceanography and ship operations to navigate back and forth on these missions with a minimum of material damage and a high degree of safety for their crews. Moreover, the northern routes to Europe during late winter and early spring present hazards to shipping in the form of large ice floes particularly around Cape Race and icebergs south of Cape Farwell (Fig. 14.1). The *Titanic* tragedy over a half-century ago is the classic example of the destructive power of an iceberg to the underwater hull of a modern steel ship. The loss of a Danish

FIG. 14.1 PACK ICE IN NORTH ATLANTIC. *U.S. Coast Guard Official Photograph*

steamer in the North Atlantic within the last decade attests to the danger of sea ice undetectable by radar in heavy weather.

In order to take advantage of the aids provided by the U.S. Government it is necessary to know what they are and how to interpret correctly and use properly the information obtainable. This chapter provides the ice oceanographic terms, examples of shiphandling in ice, hints on prevoyage preparations and some damage control measures for the mariner who will navigate in the ice.

The terms used in this chapter are those in current use by the U.S. Naval Oceanographic Office and the U.S. Fleet Weather Service which provide the U.S. Navy with its ice prediction, recommended routing, and tactical information.

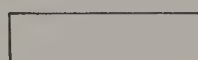
A description of ice encountered by the navigator of the higher latitudes and a description of ice encountered with definitions of important terms are outlined below:

Blink—A glare on the underside of extensive cloud areas created by light reflected from snow- or ice-covered surfaces; also observable in a clear sky. Blink caused by ice surfaces is usually yellowish-white; in contrast to snow-blink and iceblink, the sky is dark above bare land or open-water surfaces.

Bottom Ice—Ice formed on the bed of a river, lake or very shallow sea irrespective of its nature or formation.

Calving—The breaking away of a mass of ice from its parent iceberg, glacier, or shelf ice formation.

Concentration of Ice—The concentration of ice is stated in terms of the ratio of water area covered by ice to the total area observed. This ratio is expressed in tenths, with the following terms used to indicate the ice conditions of the area reported:

Term	*Description*	*Chart Symbol*
Ice free	No ice observed	
Open water	Less than one-tenth	
Very open pack	One-tenth to three-tenths	
Open pack	Four-tenths to six-tenths	
Close pack	Seven-tenths to nine-tenths	
Very close pack	Ten-tenths	

Determining size and concentration—The size of a concentration of ice is measured by the length of the major axis. A variety of sizes are encountered and they have been classified into seven categories for purposes of publishing ice information to Mariners. In the seven categories listed below the only difference that is made between brash ice and small ice cakes is that brash ice is the remnants of other forms of ice.

Brash—less than 7 feet (2 meters)
Small ice cakes—less than 7 feet (2 meters)
Ice cakes—7 through 33 feet (2–10 meters)
Small floe—33 + feet through 650 feet (10–200 meters)
Medium floe—650 + feet through 3300 feet (200–1000 meters)
Big floe—3300 + feet through 5½ nautical miles (1–10 KM)
Vast floe—More than 5½ nautical miles (more than 10KM)

The concentration of ice is merely the visual estimate of ice to water ratio of a given area.

The size of a floe may be quickly estimated by the formula:

$$1.7 \times \text{ground speed in knots} \times \text{time in seconds}$$

Floeberg—A mass of thick, heavily hummocked sea ice resembling an iceberg in appearance. Floebergs may be more than 50 feet in height. An iceberg in its last stages of disintegration may be mistaken for a floeberg.

Growler—A small fragment of ice that has been broken off an iceberg, generally greenish in color.

Hummock—A mound or hillock in pressure ice.

Fast Ice—All types of ice, either broken or unbroken, attached to the bottom of shoal areas, beached, stranded in shoal water, or attached to the shore. Fast ice may be classed as:

1. Ice foot
2. Shore ice
3. Stamuhka
4. Bottom ice

Land ice found at sea is the result of pieces of glaciers or ice shelves falling into the sea from the parent formation. This process is called calving and the term is extended to the breaking away of ice ledges from icebergs. Calving may be caused by temperature change, weight, wave or swell action and vibrations. Calving can be extremely dangerous to ships or boats that are close by when the phenomena occur.

Iceberg—An iceberg is the result of calving of an ice shelf, glacier or a larger iceberg which when afloat has a freeboard of at least 5 meters (16.4 feet). Specific types of icebergs that may be encountered are:

Tabular berg—One that has a flat upper surface, usually, very large and is mostly found in the Antarctic. Sometimes they are considered as an ice island when found in the Arctic.

Pinnacled berg—An iceberg that has weathered or eroded in such a manner that spires or pinnacles extend vertically from the main body. They are most common in the Arctic.

Bergy bit—A bergy bit is defined as having less than 5 meters (16.4 feet) of freeboard. A bergy bit may be the result of calving of a glacier, ice shelf or iceberg.

Growler—A growler is smaller than a bergy bit with barely any freeboard. It is the size of a piano.

In general, bergs are extremely dangerous because of their great underwater expanse as compared to the area showing above the surface of the water, as much as five parts under the water to one above for tabular bergs while for wing-shaped bergs the ratio is closer to one to one.

Ice topography—The topographic features in ice floes are primarily the result of pressure on the ice surface from wind, current, temperature, tides and varying densities of the ice. Pressure ice commonly found in floes is generally described more specifically by the terms rafting, ridging and hummocking.

Rafting—This phenomenon occurs when ice cakes or floes override one another and is most commonly found in young ice, since the greater thickness of older ice inhibits this occurrence.

Ridging—This takes place when pressure on a floe is sufficient to form a ridge or wall of cakes irregularly piled up in a long rugged line, frequently criscrossed and frozen together. Ridges may extend for miles and have heights up to 100 feet.

Hummocking is a mound in pressure ice and is essentially a pressure ridge which has been eroded away by age and weather. This phenomenon is primarily observed in polar ice since the process of noticeable erosion requires a significant period of time.

Water features is the term used to refer to water areas in large floes of ice. They are most important when passage through or around the pack is desired. Significant water features are:

Cracks—Cracks are small narrow breaks or fractures in the ice which may be caused by temperature, wind, current or tide. A hinge crack is one that runs parallel and adjacent to a ridge or hummock, caused by the weight of the topographical feature. A shear crack is the result of natural forces acting tangentially and simultaneously on adjacent ice areas. Tide cracks are formed between ice attached to the shore (fast ice) and adjacent ice that is afloat and is the result of the rise and fall of the ocean level due to the tidal range.

Leads are another water feature which are most important to the navigator; they are the passages through the pack ice in which a ship may proceed with some safety. Open leads are those that contain less than a one-tenth concentration of ice of any form and have an entrance from open water and an exit to open water. A blind lead is a lead that is closed by ice at one end. A constricted lead is one that is wholly or partially closed at some point or

points along its confluence. A shore lead is an opening from the sea through the pack ice to the shore. A flaw is a lead between the pack ice and the ice which is fast to the shore or aground.

Polynyas are pools of water found in an ice pack generally round or elliptical in shape. Puddles in heavy ice are often sufficiently fresh to be used for drinking.

14.1. Field Ice. Field ice has become for seamen a general term embracing virtually all types of sea ice. It is pack ice either scattered or compacted. In Fig. 14.2 the drift of sea ice is graphically analyzed. Ice has a tendency to

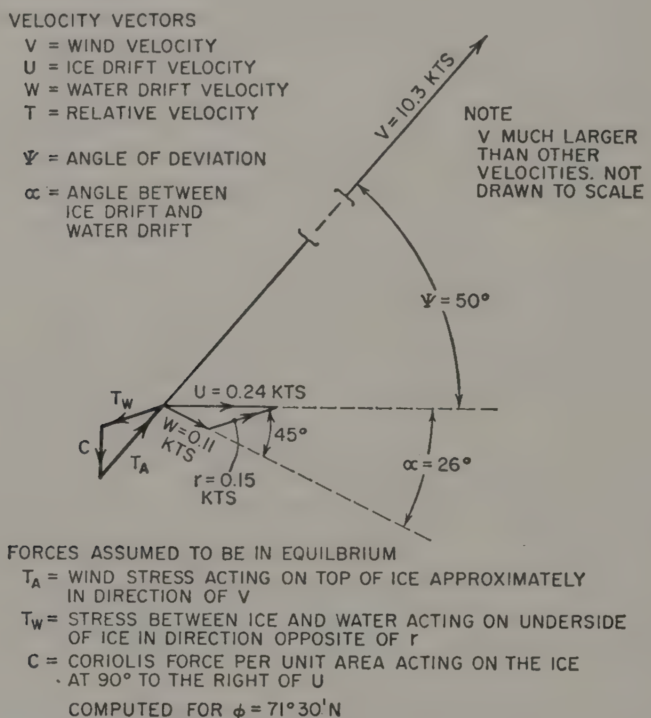


FIG. 14.2 EXAMPLE OF VECTOR RELATIONSHIP BETWEEN WIND VELOCITY AND ICE DRIFT VELOCITY

move to the right of the surface wind in the Northern Hemisphere with a speed varying from 0.01 to 0.03 of the wind speed. Coriolis force acts at right angles to the direction of ice drift. Because of the many assumptions required for the values in the theoretical formulas, empirical relationships are generally used in predicting ice drift.

The modern navigator in the high latitudes has available long range, medium range and short range ice forecasts plus optimum routing information.

Because of the differences in the geography of the poles, ice fields and

formations of ice greatly differ (see Fig. 14.3). In the Antarctic the bergs are large and tabular while in the Arctic the bergs are smaller and irregular in shape. Because the geographic configuration of the Antarctic is land surrounded by water, sea ice is generally only one year old and consequently does not

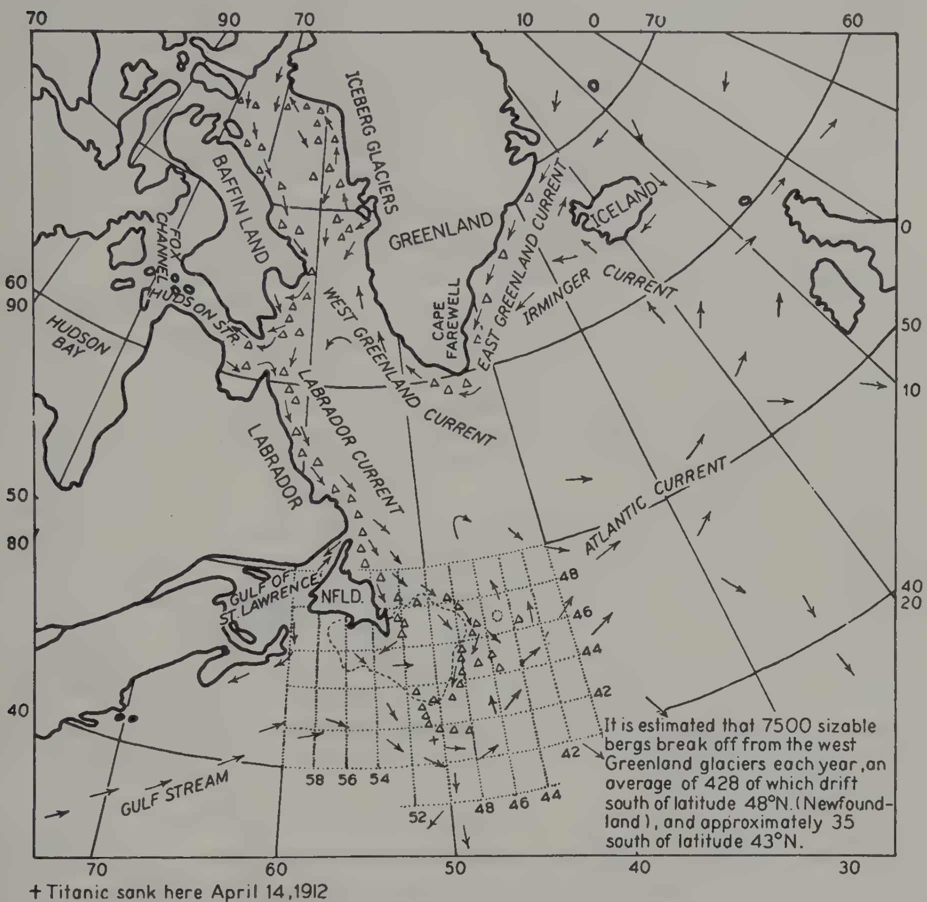


FIG. 14.3 ICEBERGS AND CURRENTS. *U.S. Coast Guard Official Photograph*

have time to build up in thickness from one winter to another. On the other hand in the Arctic the land surrounding the Arctic Ocean and the irregular geography of the land masses provide ideal conditions for the build-up of the thickness of the sea ice from one winter to the next. A thorough understanding of the geographic and topographic features of the land areas, general weather conditions and bottom contours is necessary to conduct a ship through the navigable season or wintering-over operation with safety and efficiency.

14.2. Causes of Freezing. A knowledge of the formation, growth, and decay of sea ice is desirable for an understanding of many of the problems in

ice seamanship. The climatic factors bearing on the formation of ice naturally vary from place to place and from season to season.

In temperate and tropical latitudes, the ocean acts as a storehouse of heat from the sun. The visible and infrared wave lengths are largely absorbed in the surface layers, and the heat so stored is given off to the air at night and at other periods when the air is colder than the sea surface. In higher latitudes, however, as the nights begin to grow longer in the autumn, insufficient heat is stored in the short daylight period to compensate for the losses at night, and the temperature of the surface waters is therefore lowered. As the season progresses, the altitude of the sun becomes lower day by day; less radiation is received, and more is reflected from the sea surface owing to the low angle of incidence of the rays. Finally, the water reaches the freezing point and further loss of heat results in the formation of ice.

Conditions then become even less favorable for the retention of radiant heat from the sun, since ice reflects much more of the visible radiation than does water. Cooling of the air in contact with the ice is accelerated and, as this cold air spreads, more ice is formed.

14.3. Preparations for Operations in Ice Areas. Modern steel merchant ships and most navy ships other than icebreakers are not suited for unassisted navigation in any but the most open of floating ice. A few cargo ships, built with ice-breaking bows, form a class intermediate between the sea-going icebreakers and the strengthened cargo ships. Ships of the American Merchant Marine are not so equipped or constructed, since all major ports in the United States are warm water ports and heavy ice concentrations are rarely encountered. Ships specially fitted for extensive high-latitude operations can normally navigate the majority of ice-filled waters with icebreaker assistance. However, the proportion of icebreakers to the number of ships making such a transit is greatly increased when unstrengthened ships are used. The following preparations are the minimum which should be made prior to operations in the ice.

Hull—Arrange sea connections so as to minimize the risk that is attendant with their attachment to the hull plating which is subject to ice damage. Main injections should be provided with steam connections for clearing the strainers. Ensure that all bulkheads, peaktanks, holds and voids are watertight by inspection and where possible by airtesting. Remove all projections, such as scupper guards and ringbolts, on the ship's side above and below the water line. These catch ice, slow down progress and sheer off with the attendant danger of puncturing the hull. If feasible, install timber bracing in the forepeak, using horizontal "ice beams" extending from side to side at the load water line and bearing on fore-and-aft planks placed between the frames. Additional support to the forepeak bulkhead on the side toward number one hold is desirable.

Pumps, Piping and Water Mains—Test all sounding pipes and bilge and tank pumping pipes for leaks and fractures. Check the operating condition

of all pumps not forgetting the emergency gasoline and electric portable pumps. Clean all holds, scuppers, bilges, and voids. After completion of the cleaning operation take a suction in each bilge well to ensure the system is clear for operations. Test all fire mains and risers with their connecting fireplugs and drain cocks. Just prior to entering the area of sub-freezing temperatures drain all topside fire hydrants at the lowest point between the riser and the main. Secure fresh water mains that would be subject to freezing.

Deck Equipment—Ensure that a sufficient amount of ice removal gear is available. Provide canvas covers for all exposed open boats. All exposed engines which normally use water as a cooling agent should be protected with the use of a high-grade anti-freeze. Starting cartridges should be kept available for the use of all engines whose normal starting characteristics are adversely affected by the low temperatures. The use of lightweight nylon lines in lieu of the stiffer and heavier manila and sisal is recommended. For mooring alongside the ice a sufficient number of deadmen should be made up in advance with mooring straps and toggles attached. Deadmen should be made of wooden (oak preferred) stock approximately 3 by 10 inches by 6 feet. The straps should be made up of appropriate size fiber or steel mooring line. For burying the deadmen in the ice, sufficient quantities of picks, shovels and buckets with lanyards attached should be available to the mooring party.

14.4. Anchoring. It may be advantageous to lie at anchor when in brash, but as little of the cable as possible should be payed out. The anchor windlass should be kept ready for use in the approach of large masses of pack ice. When anchoring in rotten ice in shoal water, get into the ice as far as possible to avoid the swell. But if the water is deep and ice is present, anchoring should be avoided. It may be preferable to lie to and keep power available to move the ship as the shifting floes require. It is not advisable to anchor while in pack ice, as in most cases it is useless and will probably result in the loss of the anchor and cable.

Having decided to ride to an ice anchor, choose a strong floe which can shelter the vessel from surrounding ice. To ensure as nearly as possible obtaining the shelter of a natural dock, it would be well, in making fast to a floe, to take a position where a bight is formed by two strong projections. Such places can often be found. They offer at least moderate security in the event of other ice setting out toward the ship, the projecting angles of the floes receiving the first shock.

Lay the anchor from the side of the floe where a patch of open water is formed or where the surrounding ice is least packed. When riding to an anchor the movement of the ice must be continually observed. If there is a risk of the ice surrounding the ship, weigh anchor and move into a more open region off another floe. Keep the engines ready for use on the ship; ice can frequently be avoided and permitted to drift clear by judicious use of the engines while at anchor.

In selecting an anchorage in a bay or harbor which is open to drifting ice,

the shallowest depths should be chosen, provided other conditions are suitable. A vessel should not select an anchorage too close to a glacier cliff, since calving of the barrier may endanger the ship.

In bays or fiords where fast ice exists, the tidal currents may cause this ice to drift in and out of the harbor, rendering the anchorage unsafe. Fast ice in a harbor usually moves along a tidal crack and, under the force of onshore winds, may acquire violent motion. Vessels should quit moorings at the edge of fast ice whenever onshore winds blow.

14.5. Mooring and Unloading. Although ice conditions in the Antarctic are seldom the same from one year to the next, the general condition of the fast ice in the Ross Sea changes very little, particularly in regard to offering a clear "dock space" for mooring alongside.

The thickness of the fast ice in the Bay of Whales during the months of January and February was found to be approximately 12 to 15 feet, with a height of 3 to 4 feet and with sufficient strength to hold the weight of the equipment unloaded.

Breakups occur without warning, and ships moored to the ice edge must be prepared to get underway on short notice. Sometimes cracks will develop between the ship and the barrier, but the ice may not break up for several days. Prevailing winds, and currents coming from under the barrier, tend to cause the broken pack ice to drift. With this condition a starboard-side to mooring has been found to be the most desirable.

Prior to arrival alongside the ice, all gear should be put on deck in order and line handlers instructed as to how and where to bury the deadmen and how to secure the mooring lines. Secure a manila strap and/or wire strap to each deadman, depending on the use of the hawsers and cables. Obviously if a deadman has both a manila strap and a wire strap, either wire or manila lines can be secured to it. At least four mooring lines should be ready to run with a toggle attached to the eye of each line.

It is normal practice to place the bow of the ship head-on against the ice and to hold this position by steaming ahead slowly (see Fig. 14.4). Line handling parties can then be disembarked onto the ice via Jacob's ladders. After passing over and securing the bowline and bow breast, the ship is warped around until she lays alongside the ice. Then the stern lines are put out and secured (see Fig. 14.5). This procedure of placing the bow against the ice may not be considered advisable for large vessels. If the commanding officer prefers, the line handling party may be sent to the ice by boat or helicopter if feasible and the ship held off until the deadmen are planted and all preparations made to receive the mooring lines. Then the ship can be brought alongside in the normal manner of making fast to a pier.

Plant deadmen (see Fig. 14.6) well in on the ice shelf so that an almost horizontal pull will be made on the mooring lines when hauling the ship alongside. A trench for a deadman should be dug about 4 to 6 feet deep with sides at a slight angle, as shown in Fig. 14.6, in order to give better holding

power and to avoid the tendency to pull the deadman out before it is well frozen into place. The deadman with the manila strap attached is buried in the hole and covered over with ice. A few buckets of water thrown on top of the fill will help freeze it in place in a few minutes. The mooring line is

FIG. 14.4 *U.S.S. NESPELEN AOG-55 WITH BOW AGAINST ICE SHELF. Official U.S. Navy Photograph*

passed through the eye of the strap that protrudes up through its own part for quick release. Check toggles frequently to see that they are free for easy slipping. If wet snow or sleet falls, they may become frozen in place.

Four mooring lines distributed as shown in Fig. 14.6 are recommended. The number should be kept to a minimum to keep the ship safely secured and also to facilitate a hurried unmooring to clear the area during breakup. Telegraph poles 12 to 16 feet long, hung vertically over the side of the ship, make the best fenders. There is usually some ground swell in the Bay of

Whales which will cause a ship to work up and down. Cane fenders have a tendency to ice up and may catch on the edges of the shelf ice.

The use of ice anchors in mooring alongside the Antarctic shelf is generally not recommended. The surface of the ice is too soft to provide adequate holding power. Mooring to timber with strap and toggle requires less man-power, makes weighing much easier and quicker, and eliminates the possibility of losing an expensive metal anchor. Figure 14.7 illustrates the height of barrier ice in comparison to the size of a ship.

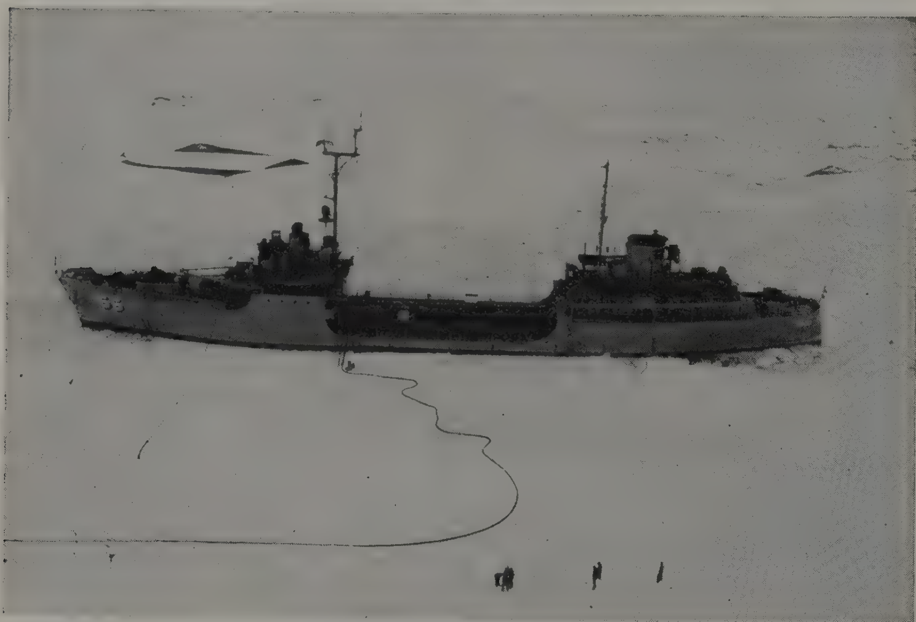


FIG. 14.5 U.S.S. NESPELEN (AOG-55) MOORED ALONGSIDE ICE SHELF. *Official U.S. Navy Photograph*

Alongside Offloading—Ships should moor as close to the ice as practicable in order to reduce the offloading time to a minimum. Keep the ship ready for unmooring and getting underway. If more than one ship is moored in the same vicinity the situation should be explored with the other commanding officer and coordinated plans made for safe departure.

Material should be unloaded only as fast as it can be moved inland. Skidding of heavy weights from the ship to the ice is not recommended unless shelf ice conditions appear to be exceptionally good and no crevasses are observed between the ship and the barrier. When skidding of cargo is deemed necessary heavy cribbing made up of telegraph poles should be used to distribute the weight as far inland as possible.

In the Arctic, unloading cargo over the ice is considered practical over landfast or landlocked ice, but not over ice in the open areas. Fast, smooth ice presents no difficulties for trucks or tractors provided it is thick enough

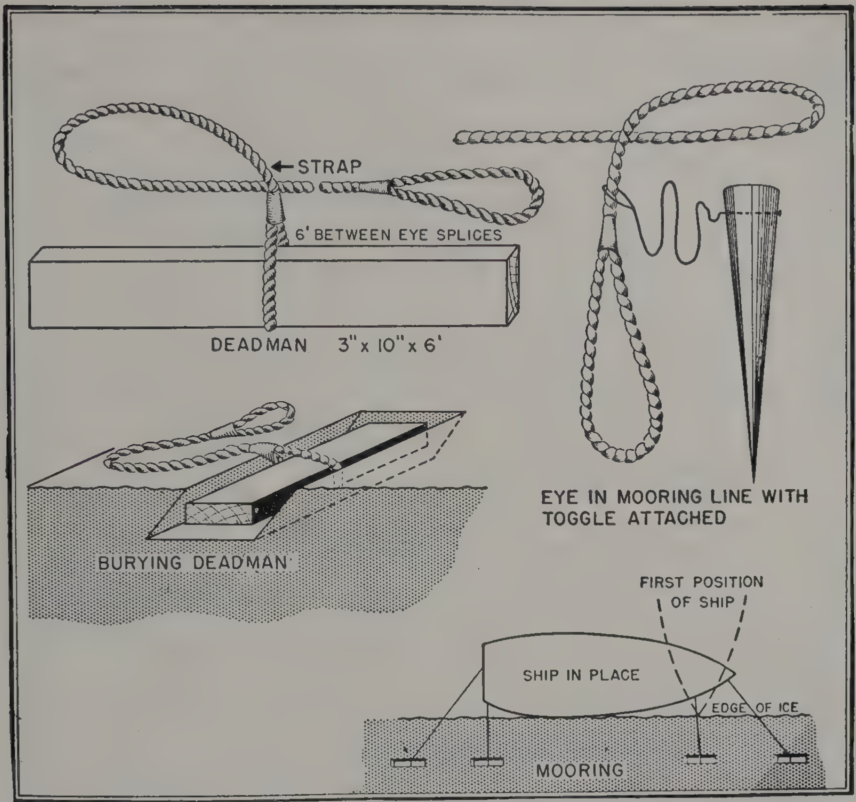


FIG. 14.6 MOORING TO ICE SHELF

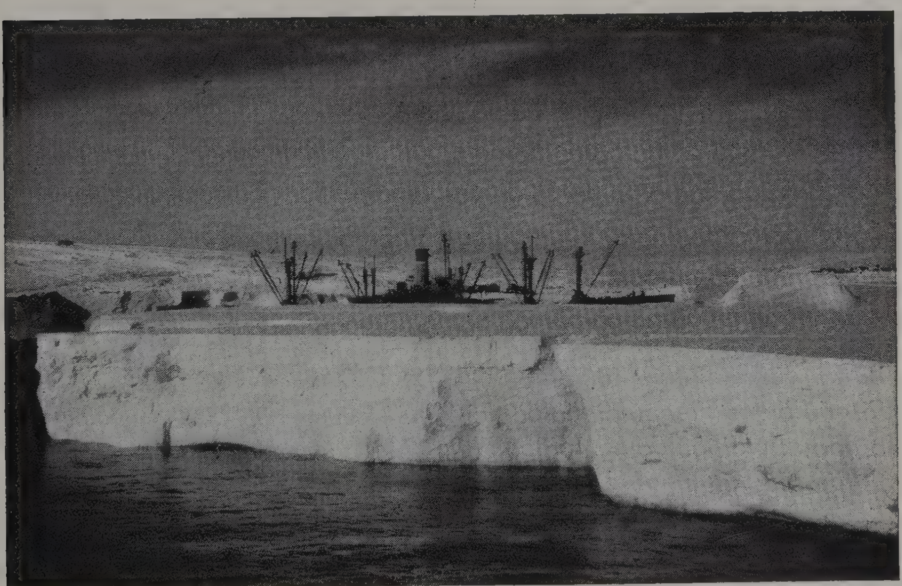


FIG. 14.7 UNLOADING ON ICE BARRIER. *Official U.S. Navy Photograph*

to support the weight. Rough, hummocky ice is more difficult but can be traversed by careful selection of the route and the use of a small bulldozer. In the event the ice is covered with soft snow and there are large amounts of cargo to be landed, a metal landing strip mat serves very well to make a smooth roadway to the beach. In landlocked areas during the winter months, natural slips for unloading can be cut out by an icebreaker, thus entirely eliminating the problem of mooring lines or deadmen. It is recommended that landlocked areas be selected and checked by aerial observation before planning large-scale over the ice movements of cargo.

14.6. Navigating the Single Ship in Ice. In general, ice is an obstacle to the progress of any ship and is dangerous to ships which, by their construction, were not intended for navigation through the ice. It is possible, nevertheless, for the ordinary, unprotected ship to safely navigate through open pack during the long periods of summer daylight during which the visibility is adequate to mark dangers and navigational hazards.

When a ship encounters ice lying on her course, a decision must be made whether to attempt to penetrate the ice or to steam around it. If the boundaries of the ice are in sight, do not enter, but skirt to the windward. In the case of larger ice areas, unless they fill straits through which the ship must pass or completely block access to her port of destination, time and fuel will be saved by taking the longer way around the ice zone.

When conditions make it necessary to enter the ice, the point of entry should be selected with great care. Make a thorough reconnaissance with all of the facilities that are available and feasible to use. The following principles govern the choice of the place of entry:

1. Consider the penetrability of the ice along the proposed course inside the edge of the ice field, with regard both to the thickness and the degree of consolidation.

2. Never enter the ice where pressure exists as evidenced by tenting or rafting.

3. If possible, enter the ice upwind. The windward edge of an ice field is more compact than the leeward edge. If it is necessary to enter downwind, use great care to avoid the damage to the hull of the ship through collision with the ice cakes. Always enter perpendicular to the edge of the ice.

4. If the ice is thick and drifting rapidly, wait for a change in the direction of the ice movement which may be accompanied by an improvement in ice conditions. Take into account the time of ebb and flood tide; ice generally becomes more compact on the flood tide but begins to break up on the ebb.

5. The ice edge is usually not straight, but often has projecting tongues between bights. Enter at such a bight, for here the surge will be the least.

6. Enter at the slowest possible speed to reduce the force of the initial impact on the stem. Once the bow is in the ice and is cutting or pushing the ice aside, increase power to avoid losing headway and adjust revolutions thereafter in accordance with the state of the ice.

7. While moving through pack ice keep in mind the following:

   a. Keep moving.
   b. Work with the ice, not against it.
   c. Do not rush; be patient.
   d. Stay in open water or leads as far as possible.
   e. Keep a good watch on your propellers.
   f. Avoid striking a large piece of ice if you can go around it. If you must strike it, do so head-on.

14.7. Convoying in Ice. An ice convoy consists of one or more ships, whether strengthened for ice navigation or not, accompanied by one or more icebreakers. Either the icebreakers or the escorted ships may be naval ships.

There are three types of ice convoys:

1. Single ship convoy.
2. Simple convoy; one icebreaker escorting a group of ships.
3. Composite convoy; two or more icebreakers escorting several ships.

A simple convoy consists of several transports or other ships and one leading icebreaker. The captain of the leading icebreaker decides upon the number of ships that he can take through at one time. His decision depends on the type of ships which are to follow the icebreaker and the condition of the ice enroute. If the ships to be convoyed are reinforced for ice navigation and have sufficiently powerful engines, an icebreaker can take an average of four of them through an ice coverage of 70 to 80 percent. If the conditions are more favorable, only 50 to 60 percent ice, the number of ships can be increased. If there is close pack with over 80 percent coverage, the number of ships must be limited to one or two. Figure 14.8 shows an icebreaker making a channel for ships to follow.

FIG. 14.8 ICEBREAKER MAKING A CHANNEL

The arrangement of the convoy should be carefully worked out. The varying ice conditions in the area along the route and the variety of ships forming the convoy must be taken into consideration. The first factor to be considered is the power of the ships. The weakest, as a rule, are placed immediately after the icebreakers, so that they can avoid striking ice obstacles and be able to move in a comparatively clear channel. The most powerful and beamiest

FIG. 14.9 TWO ICEBREAKERS KEEPING A CHANNEL OPEN. *Official U.S. Navy Photograph*

ships are placed in the convoy so that less powerful ships can proceed in their wake. Consideration also must be given to whether a ship is loaded or in ballast. Finally, it is essential that one of the most powerful ships in the convoy be placed in the last position.

A composite convoy consists of two or three simple convoys. The number of ships to each icebreaker and their place in the column is determined in the same way as for a simple convoy. The difficulty of controlling from a position in front is an important drawback to this type of convoy, which frequently stretches out over a distance of 1½ to 2 miles. The first icebreaker is designated the leader; the others are placed according to orders of the leader's captain, either in column or in line of bearing for breaking out.

The operating procedure is for the most powerful icebreaker to lead the convoy, breaking a channel in the ice without stopping to break out other ships. Following the leader at a distance decided upon by the leader's captain are two or three ships, the weakest in the entire convoy. The second icebreaker proceeds astern of the first group, followed by two or three ships, and so on. Figure 14.9 shows two icebreakers working in unison to keep a channel open for ships to proceed through and to moor. The assignment of the second icebreaker is to break out the ships ahead of her so that the leader will not have to return to them and thus delay the convoy. The second icebreaker, on receiving a signal "stuck" from any of the proceeding ships, increases speed, leaves the column, and breaks out the ship. When the latter is freed and moving, the icebreaker resumes her previous station in the column. The same action is taken by the second icebreaker upon hearing the same signal from one of the ships astern, provided there are no more icebreakers in the convoy. If there is a third icebreaker, she breaks out the ships following the second icebreaker. Ships must be broken out while proceeding, in order not to delay the progress of the entire convoy.

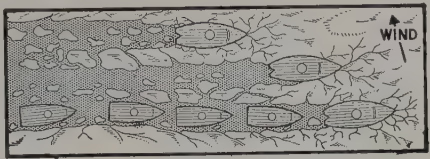


FIG. 14.10 LINE OF BEARING FOR BREAKING OUT

When several icebreakers are present in line of bearing for breaking out, they follow behind the leader at a set distance to leeward (see Fig. 14.10) in such a way as to thin out the ice in the channel made by the leader, and remain always in readiness for breaking out or towing any ship that gets stuck or lags behind.

A final caution should be observed by all mariners in polar and subpolar waters. Radar, while invaluable in detecting icebergs, cannot distinguish brash or block ice in rough seas. The utilization of all observation facilities available to the mariner should be used to the maximum that is feasible when traversing ice infested waters.

Part III

RULES OF THE ROAD

15

Rules of the Road—Principles and Application

15.1. History. The need for uniform Rules of the Road arose when steam vessels with higher speeds than sailing vessels appeared on the trade routes of the world. The modern Rules date from 1863 in which year Great Britain and France adopted uniform regulations for the prevention of collisions at sea.

The Congress of the United States approved a law on April 29, 1864, containing Rules similar to those already adopted by Great Britain and France. About 1885, Belgium, Denmark, Germany, Japan, and Norway accepted the same Rules as Great Britain, France, and the United States.

The President of the United States called in 1889 a Conference of all Maritime Nations to draw up Rules and Regulations for the safety of lives and property at sea. The Conference approved the International Rules of the Road, 1889, which were accepted and used by all maritime nations until a 1948 revision was adopted and put into effect in 1954.

In 1948 a Conference was held in London which approved changes in the 1889 Rules, which clarified and simplified them. More important, the 1948 Rules in process of modernization included the seaplane among seagoing vessels. The 1948 Rules were known as the International Regulations for Preventing Collisions at Sea, 1948. They were adopted by the United States by Public Law 172, 82nd Congress, approved October 11, 1951, and became effective January 1, 1954. They remained in effect until September 1, 1965.

The most recent International Conference was held in the spring of 1960. As an outgrowth of this Conference, the 1948 Rules were changed in many ways to further reflect our changing times. The most significant revision concerns conduct in restricted visibility. A new rule 16(c) was adopted to provide for safe navigation by a vessel which detects another vessel outside of visual or audible range. Though not mentioning radar specifically, this rule—when considered together with the preliminary paragraphs to part C and the annex entitled "Recommendations on the Use of Radar Information as an Aid to Avoiding Collisions at Sea"—resolves several important questions which presently exist concerning a vessel navigating with the aid of radar.

Other changes of interest are: (a) Vessels are defined by their length rather than by tonnage; (b) the use of a white light synchronized with the prescribed

whistle signals is permitted; (c) requirements for special lights for ships unable to get out of the way of approaching vessels because of the nature of their work were extended to ships replenishing at sea and ships engaged in the launching or recovery of aircraft; (d) a new provision was added concerning lights and shapes for minesweeping vessels; (e) rule 9, lights for fishing vessels, was almost completely rewritten; (f) rule 17, the sailing rule, was modernized; (g) rule 22 was strengthened to require that a vessel which is directed by these rules to keep out of the way of another vessel shall, so far as possible, take positive early action to comply with this obligation; (h) a new rule was added requiring that in a narrow channel a power-driven vessel of less than 65 feet in length shall not hamper the safe passage of a vessel which can navigate only inside such channel; (i) a requirement that a tug and tow carry a prescribed shape in daylight was adopted; (j) specific authorization was provided for the permissive use of navigation lights in daylight in restricted visibility; (k) a definition of "engaged in fishing" was added to include fishing with nets, lines or trawls but not fishing with trolling lines; and (l) the permissive use of colored masthead identity lights by sailing vessels was authorized.

The effective date of the 1960 International Rules was September 1, 1965. They were enacted by the United States as Public Law 131, 88th Congress, on September 24, 1963, and declared effective on the date indicated by Presidential Proclamation. Other countries by similar process made these Rules effective on the same date.

The Inland Rules of the Road were approved by Congress on June 7, 1897, and made effective October 7, 1897. There have been some later additions and amendments. However, they are in need of further revision and should be made more uniform with the International Rules.

The line of demarkation between the waters under the International and the Inland Rules was originally set forth by the Secretary of the Treasury under the Act of February 19, 1895. Some changes and additions have been made since that time. The Commandant of the U.S. Coast Guard is now charged with the determination of this boundary line which is shown on all charts.

The boundary line for seaplanes on the water is not the same as that for vessels. Public Law 131 states that the International Rules of the Road "shall not apply . . . with respect to aircraft in any territorial waters of the United States." Civil Air Regulations in 14 CFR Parts 3 and 60 apply to seaplanes on the water in United States territorial waters.

The Statutory Rules for the Great Lakes and Western Rivers were enacted by Congress on February 8, 1895, and May 21, 1948, respectively.

The Pilot Rules (3) for Inland Waters, for the Great Lakes, and for the Western Rivers were originally issued by the Board of Supervising Inspectors for Steam Vessels, Department of Commerce, under the Acts of June 7, 1897, February 8, 1895, and R.S. 4412, respectively. The authority to issue Pilot

Rules has now been transferred to the Commandant of the Coast Guard by Executive Order 9083 of February 28, 1942, effective March 1, 1942, and reaffirmed by subsequent Reorganization Plans. The three Pilot Rules supplement the Inland, Great Lakes and Western Rivers Rules, but they do not supersede those statutory Rules. The Pilot Rules have the force of statute, but they are not "judicially noticed." They must be proved in court. Courts can and have ruled certain Pilot Rules void because they conflicted with the statutory Rules.

15.2. Various Rules of the Road. All public and private vessels of the United States are required by law, regulation, and court decision to comply strictly with the following "Rules" for preventing collisions and related laws and regulations, namely:

1. International Rules of the Road, agreed to internationally and enacted by Congress. These Rules are applicable on the high seas, outboard of the boundary line, and in certain foreign waters.
2. Inland Rules of the Road enacted by Congress and used on Inland waters of the U.S., inboard of the boundary line, except on the Great Lakes and Western Rivers.
3. The Pilot Rules for Inland Waters prescribed by the Commandant of the U.S. Coast Guard for the above Inland Waters.
4. The Great Lakes Rules enacted by Congress for use on the Great Lakes and connecting and tributary waters as far east as Montreal.
5. The Pilot Rules for the Great Lakes issued by the Commandant of the Coast Guard.
6. The Western Rivers Rules, enacted by Congress and effective on the Red River of the North, Mississippi River, and waters tributary to the latter.
7. The Pilot Rules for Western Rivers, by the Commandant of the Coast Guard.
8. General Regulations of the Corps of Engineers, Department of the Army, applicable to the Great Lakes.
9. The Motor Boat Act of 1940, applicable to every vessel propelled in whole or in part by machinery and not more than 65 feet in length, except tugboats and towboats propelled by steam. It is effective in all U.S. waters.
10. Miscellaneous U.S. Statutes, i.e., Helm Order Act; Stand-by Act; Wreck Act; Death on High Seas Act; Naval Lights Act; Anchorage Act of March 3, 1899.
11. Panama Canal Rules.
12. Hawser Rules for tows in Inland Waters, prescribed by Commandant of the Coast Guard.
13. Anchorage Regulations issued by the Corps of Engineers, Department of the Army.

14. Statutes of the several states of the United States.
15. Decisions of U.S. Courts.
16. Customs accepted by the Courts.
17. Foreign Inland Rules in those foreign waters.

15.3. Basic Principles of International and Inland Rules. The International Regulations for the Prevention of Collisions at Sea, 1960, and the Inland Rules are based on the following principles, as interpreted by U.S. Courts:

a. Vessels affected.
b. Location.
c. When effective.
d. Mandatory.
e. Maneuverability.
f. Burdened and privileged vessels.
g. Obedience in time.
h. Shifting responsibility.
i. Assumptions.
j. Rule 27 (General Prudential Rule).
k. Customs.
l. Ferries, fire boats, vessels docking and undocking, getting under way.
m. Jurisdiction.
n. Legal personality.
o. Court decisions.
p. Unequal fault, equal responsibility.

15.4. Vessels Affected by the Rules. The law states that the Rules "shall be followed by all public and private vessels of the United States, and by all aircraft of United States registry. . . ." Hence the Rules must be obeyed by naval and merchant vessels, fishing vessels, ferries, tugs with tows, vessels being towed, yachts, power-driven and sailing vessels, pilot vessels, dredges, seaplanes on the water, in fact, by every vessel afloat.

15.5. Location. All of these vessels must comply with the Rules which apply to the place where the vessel is operating. The International Rules are effective on the high seas, beyond the boundary line separating the high seas from U.S. and foreign Inland waters. The Inland Rules and Inland Pilot Rules must be obeyed in Inland waters, except on the Great Lakes and Western Rivers. Seaplanes must obey the International Rules outside of territorial waters and the Civil Air Regulations within these waters.

15.6. When the Rules Apply. The exact time when the Rules must be applied is difficult to define. Mr. Justice Clifford, in the N.Y. AND LIVERPOOL CO. *v.* RUMBALL, said, "Rules of navigation . . . are obligatory upon vessels approaching each other, from the time the necessity for precaution begins and continue to be applicable as the vessels advance, so long as the means and

opportunity to avoid danger remain. They . . . are equally inapplicable to vessels of every description, while they are yet so distant from each other that measures of precaution have not become necessary to avoid a collision." A British judge, Lord Esher, in the BANSHEE, said, "They [the Rules] only apply at a time when, if either of them [vessels] does anything contrary to the Regulations, it will cause danger of collision. None of the Regulations apply until that time has arrived."

15.7. Risk of Collision. The International Rules, 1960, and the Inland Rules prescribe certain "Steering and Sailing Rules" which must be followed when two vessels are approaching each other ". . . so as to involve risk of collision. . . ." Justice Longyear, in the MILWAUKEE, said, "Risk of collision begins the very moment when the two vessels have approached so near each other and upon such courses that by a departure from the rules of navigation . . . , a collision might be brought about."

Part D, Steering and Sailing Rules, International Rules, 1960, and Part IV, Inland Rules, state: "Risk of collision can, when circumstances permit, be ascertained by carefully watching the compass bearing of an approaching vessel. If the bearing does not appreciably change, such risk should be deemed to exist." This caution might be extended to the distance where the two approaching vessels are so far apart that either one or both could change course or speed without affecting the other vessel. It is reasonable to state that risk of collision is involved when "the bearing does not appreciably change" and when the approaching vessels are so close that the movements of one does affect the other and when "by a departure from the rules of navigation . . . a collision might be brought about."

15.8. Mandatory. The Rules are mandatory and are not optional. There is no choice of action until the collision is so imminent that both vessels must take action.

Justice Fuller, in BELDEN *v.* CHASE, stated that the Statutes and the Pilot Rules "are not merely prudential regulations, but binding enactments. . . . Obviously, they must be rigidly enforced, in order to attain the object for which they were framed, which could not be secured if the masters of vessels were permitted to indulge their discretion in respect to obeying or departing from them."

15.9. Ability to Maneuver. Both Rules are based, *in part,* on the premise that certain vessels are unable to maneuver as quickly and as easily as other types of vessels. The more maneuverable is required, therefore, to keep clear of the less maneuverable. An example is the rule which requires power-driven vessels to keep out of the way of sailing vessels except when the sailing vessel overtakes the power-driven vessel. There is a Rule for each case.

15.10. Burdened and Privileged Vessels. The terms *Burdened* and *Privileged* vessels are often used to indicate the vessel which must give way and the vessel which must hold its course and speed when there is risk of collision. The terms are expressive but misleading because each vessel is required by the

Rules to act in a certain manner. For example: "Where two power-driven vessels are crossing, so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way of the other." (Int. Rule 19.) "Where by any of these Rules, one of the two vessels is to keep out of the way, the other shall keep her course and speed. . . ." (Inland Article 21.)

15.11. Obedience in Time. It is important that the Rules be obeyed in time to avoid the immediate risk of collision, to give the other vessel an opportunity to understand the situation, and to take proper action. "The Rules must be obeyed when the vessels are far enough apart to adopt these maneuvers deliberately and safely." (The TRANSFER No. 10.)

15.12. Shifting Responsibility. The Courts have ruled, in many cases, that, when two vessels are approaching each other so as to involve risk of collision, the original responsibilities under the law cannot be changed by the subsequent movements of either vessel until the collision is so imminent that both must take appropriate action under Rule 27 or until the risk of collision exists no longer. In other words, no subsequent change in bearing or distance, after risk of collision is involved, will alter the fact that one of the vessels must keep clear and the other hold her course and speed. Of course, the time may come when there is no right of way and, therefore, each vessel must take measures to avoid the collision which is imminent. When the risk of collision exists no longer, the Rules apply no longer and a different situation may then arise. This principle is the reason that the old "port the helm" rule is bad seamanship and bad sea manners.

15.13. Assumptions. In order that a collision may be avoided after risk of collision exists, it is necessary that the movements of one vessel—the privileged one—must be known so that the other vessel—the burdened one—may change her course and speed, if necessary, to keep clear. A vessel has the right to assume that the other vessel will obey the Rules of the Road, will be navigated with care and attention, will keep to its own side of a channel, etc. However, the assumption does not hold when it is evident that the other vessel is not being navigated with care and attention. For example, a privileged vessel in a crossing situation should not hold its course and speed until collision results. Justice Longyear, in the MILWAUKEE, said, "It is true, prima facie, each has the right to assume that the other will obey the law. But this does not justify either in shutting his eyes to what the other may actually do, or in omitting to do what he can to avoid an accident, made imminent by the acts of the other."

15.14. Rule 27—General Prudential Rule. This Rule does not apply in every case where it suits the convenience of the vessel to use it. On the contrary, the other Steering and Sailing Rules should be strictly adhered to, in most cases. But the object of the Rules is to prevent and not cause collisions. There have been and will be many different situations. In order to cover *all* situations, this Rule (27) was added. It should be obeyed where collision is

imminent and where both vessels must take further action to avoid collision. Until this point is reached, the other Steering and Sailing Rules should be applied.

15.15. Customs. Customs are not judicially noticed. They must be proved in each case; they must not conflict with the statutes and regulations; and they must be reasonable in view of a particular, permanent, local condition. Some customs have been accepted by the Courts, whereas some have not. "Moreover, each vessel has the right to assume that the other will conform to the requirements of an established usage, and must govern her own conduct accordingly"—Justice Wallace in the ALASKA.

15.16. Ferries, Fire Boats, Vessels, Docking, Undocking and Getting Underway. Ferries have a right to "make" and leave their slips. While they are doing so, if they are not on a steady course, the meeting, crossing, or overtaking rules do not apply and Rule 27 applies. Justice Ward, in the JOHN RUGGE, said, "The Steering and Sailing Rules apply to vessels navigating on steady courses. Where one of them is maneuvering merely, as, for instance, to get into or out of a dock, or, as in this case, winding around to get on her course, the situation is one of special circumstances, under Article 27 of the Inland Regulations which requires each vessel to act prudently."

In a like manner, a vessel has a right to dock or undock. Other vessels should not to pass so close to the end of a pier as to restrict the movements of such vessels, entering or leaving a slip or dock. The regular Steering and Sailing Rules apply to such vessels if they are on a steady course, i.e., one where their future position can be ascertained. The Special Circumstances Rule (27) applies when they are not on a steady course.

A vessel getting underway is within her rights, too. Approaching vessels must apply Rule 27 until the former vessel has turned to a steady course. The meeting, crossing, or overtaking rules do not apply until that time.

A vessel backing out into a river or channel from a dock and turning preparatory to standing out must be allowed a reasonable amount of room to turn. Other approaching vessels should apply Rule 27 and not meeting, crossing, or overtaking rules.

A fire boat is subject to the Rules of the Road, but other vessels should recognize the urgency of her errands and make some allowance.

In all of these cases, the vessels concerned are subject to the Rules of the Road, and the only question is which Rule to apply. If the ferry entering or leaving her slip or the vessel getting underway, docking, or undocking is not on a steady course, Rule 27 applies. If they have steadied on one course, the other Steering and Sailing Rules apply, i.e., meeting, crossing, or overtaking.

15.17. Jurisdiction. When collision between vessels occurs in navigable waters used in interstate commerce, the case can be heard in the Federal Courts sitting as Courts in Admiralty. The District Courts are the trial courts, the Circuit Courts hear appeals, and the Supreme Court may hear the final appeal. If the collision occurs on waters wholly within a state, the state courts have

sole jurisdiction. If the collision occurred on waters in or between two states which empty into the sea, there is concurrent jurisdiction. Either the Federal or state court may hear the case.

When a vessel runs into a pier or bridge through negligence or bad seamanship, the Admiralty Courts have no jurisdiction. On the other hand, if a bridge or draw damages a vessel due to improper construction or operation, the case can be heard by an Admiralty Court.

15.18. Legal Personality. A merchant ship is liable *in rem* (against a thing) for the faults of her master, officers, or men (perhaps a lookout) operating the ship. She can be sued in an Admiralty Court, attached, and sold to satisfy a judgment. The owners are not otherwise liable in such suits unless they have contributed to the fault by neglect, privity, or knowledge.

The Sovereign cannot be sued because one of her vessels, i.e., a naval vessel, has collided with a merchant vessel unless she has granted such privilege. Congress has approved such proceedings, but a naval vessel cannot be seized and thus placed out of commission or sold to satisfy a judgment.

15.19. Court Decisions. The Federal Courts in Admiralty determine the legal meaning of certain words in the Rules, such as "moderate speed," and interpret phrases such as "whose engines are going at full speed astern. . . ." (Inland Rule, Art. 28.)

15.20. Unequal Fault, Equal Responsibility. U.S. courts have held that where both vessels are in fault in a collision the liability of each vessel is one half of the total loss. However, if the fault of one is great and that of the other is minor, nonstatutory, and noncontributory, the courts may not inquire fully into the minor fault or they may disregard it and order the full costs to be paid by the vessel with the major fault.

15.21. Subdivision of International Rules. Read the International and Inland Rules in the following chapters. It will be noted that the International Rules are divided into: Part A, Preliminary and Definitions; Part B, Lights and Shapes; Part C, Sound Signals and Conduct in Restricted Visibility; Part D, Steering and Sailing Rules; Part E, Sound Signals for Vessels in Sight of One Another; and Part F, Miscellaneous. This arrangement differs from the 1948 Rules, in that Part B is confined to lights and shapes; a new Part C is devoted to action in fog and other conditions of restricted visibility; Part D includes only maneuvering Rules for vessels and seaplanes in sight of each other; and new Part E sets out sound signals for vessels in sight taking avoiding action.

15.22. Subdivision of the Inland Rules. The Inland Rules have not been changed. They contain four parts: Part I, Enacting Clause, Scope, Penalty and Preliminary Definitions; Part II, Lights and so forth; Part III, Sound Signals for Fog, and so forth; and Part IV, Steering and Sailing Rules.

15.23. Structure of the International Rules. The student should notice that the International Rules contain four important parts, if the preliminary definitions and the miscellaneous Rules are not so considered. The first of these

parts, Part B, "Lights and Shapes," describes the lights and daytime shapes which various kinds of vessels show in order that other vessels may recognize them. The second part, Part C, "Sound Signals and Conduct in Restricted Visibility," specifies identifying signals to be given when vessels cannot see each other, and also the avoiding action to be taken in such cases. The third part, Part D, "Steering and Sailing Rules," prescribes the maneuvers which vessels shall make, when in sight of each other, to avoid collision, having recognized and located the other vessel by her appearance, lights, or shapes. The fourth part, Part E, "Sound Signals for Vessels in Sight of One Another," describes the clear weather signals which must be given when taking action under Steering and Sailing Rules. Part B applies in all weathers. Part C is used only when the existing visibility prohibits vessels from seeing each other. Parts D and E are used jointly whenever vessels are visible to each other.

The next point to note is that vessels are divided generally into those at anchor, those under way, and those unable to maneuver easily and quickly. Vessels at anchor show anchor lights or, by day, an anchor ball. Vessels under way show (or flash, for sailing pilot vessels) side lights. Those unable to maneuver show special lights at night, usually a combination of red, green, or white in a vertical line and identifying shapes by day. The lights required on seaplanes are similar to those prescribed for other vessels.

To distinguish at night between power-driven and sailing vessels under way, the former carry a 20-point white light above the side lights. If the vessel is 150 feet or more in length, she must show a second 20-point white light, either forward and below or abaft and above the first (masthead) white light to form a range. The after light is always higher and it is generally called the range light.

The range light is a mandatory, instead of optional, requirement in the International Rules. It differs in character from the Inland Rules because it is a 20-point light, whereas the Inland Rules require an all-around white light for nonseagoing vessels.

Sailing vessels and any vessel being towed do not carry masthead or range lights. However, under the 1960 Rules, sailing vessels are permitted to show a red light over a green light from the top of the foremast to indicate that they are under sail.

15.24. Structure of the Inland Rules. The Inland Rules are assembled in the same general manner as the International Rules. The lights and shapes to aid recognition are found in Part II, but fog signals are placed in a separate Part III, although they are sounds used to aid recognition. Part IV contains the Steering and Sailing Rules and, in addition, miscellaneous Rules, i.e., whistle signals, seamanship, naval lights, distress signals, and orders to helmsmen. In other words, the subdivision of the Inland Rules is not as consistent and reasonable as the International Rules.

However, the Inland Rules divide vessels into three general classes in the same manner as the International Rules, i.e.: (a) vessels at anchor, (b) those

under way, and (c) those unable to maneuver. The classes are distinguished in the same general manner, although the details vary. Seaplanes are not mentioned in the Inland Rules—a serious defect. The Rules for Aircraft on the water in U.S. waters will be found in the Civil Air Regulations. At present, they conform generally to Inland Rules. However, there is appreciable reliance on the "General Prudential Rule," Article 27, which provides for departure from the Rules in "special circumstances."

Power-driven (called "steam" in the Inland Rules) vessels and sailing vessels are distinguished in the same manner as in the International Rules insofar as the masthead and range light are concerned. No provision is made in Inland Rules for special identifying lights.

The differences and similarities between the two Rules will be pointed out in the following chapters.

15.25. Pertinent Statutes. *Anchorage Act*—A vessel has a right to anchor. The only question is: "Where can she anchor legally?" Certain water areas are designated by the Secretary of the Army as anchorages. (U.S. Act of March 4, 1915.) It is improper, although not unlawful, to anchor outside of these areas in restricted waters, save in an emergency. (The RICHMOND, 63 F 1020.) A vessel has a right to anchor in large, navigable water areas such as Chesapeake Bay or on soundings off the Coast. (LE LION, 84 F 1011.) The Anchorage Act of March 3, 1899, states: "It shall not be lawful to tie up or anchor vessels or other craft in navigable channels in such a manner as to prevent or obstruct the passage of other vessels or craft. . . ." The trend of judicial opinion has been to permit anchorage in a channel, "but to forbid them [vessels] from doing so in such a manner as to obstruct said channels or render their navigation difficult or dangerous." (JOB H. JACKSON, 144 F 896.) Channels are primarily for traffic and not for anchorage. It is sometimes necessary to anchor in a narrow channel—in a thick fog—but the anchorage should be shifted to an authorized anchorage ground as soon as possible. While the vessel remains in the narrow channel, every precaution to prevent collision should be taken such as: (a) use a short scope of chain, (b) keep power on the anchor engine, (c) station a watch in the engine room and keep steam up to the throttle, (d) station a watch on the bridge, (e) post extra lookouts.

Of course, if the channel is well lighted, marked, and wide and there is plenty of room for other vessels to pass, a vessel may remain at anchor there without violation of the statute. An example is the Hudson River off 96th Street, New York. Even so, she should anchor to one side of the channel, and be particularly careful that: (a) her anchor lights are showing, (b) a trained lookout is posted, (c) proper signals are sounded in a fog, and (d) the anchor ball is hoisted by day.

Attention is called to Article 11 of the Inland Rules which permits the Secretary of the Army to designate "special anchorage areas" where vessels not more than 65 feet in length may anchor and "not be required to carry or exhibit an anchor light." Such areas are usually near yacht clubs or marinas

and are intended primarily for pleasure craft, secured for the night. However, a recent change to Inland Rules permits nondescript craft, such as barges, canal boats, or scows to anchor in these anchorages with but one anchor light irrespective of the length of the vessel or, if in a group, the length of the group.

After the vessel has anchored in accordance with her legal rights, she must exhibit the proper lights at night, sound correct fog signals when necessary, and post a watch on deck. Sufficient trained lookouts must be stationed to inform the officer in charge of the ship of the approach of other vessels or objects which might require action.

An anchored vessel is presumed to be without fault if a moving vessel collides with her unless the moving vessel can prove that the collision "was the result of inevitable accident" (VIRGINIA EHRMAN, 97 U.S. 309) or that the anchored vessel was in fault (OTTO MARMET COAL CO. *v.* FIEGER CO., 259 F 435). The moving vessel must proceed lawfully in moving through an anchorage ground. Tides and current do not excuse her (STROUT *v.* FOSTER, 42 U.S. 89).

The anchored vessel may be found in fault if she has failed to anchor in a legal position, show the proper lights, or sound the proper fog signals. She may also be found in fault if she: (a) anchors without necessity in a narrow channel; (b) swings to the tide and obstructs the channel substantially; (c) anchors on a frequented compass course when a safer anchorage is available; (d) fails to move from a channel when possible; (e) fails to move when warned that her position is dangerous; (f) anchors where approaching vessels rounding a point sight her suddenly and belatedly; (g) fails to veer chain or use her helm when such action might prevent a collision, the moving vessel having done all in her power to avoid a collision; (h) anchors so close to another anchored vessel as to foul her when swinging (JUNIATA, 124 F 861); (i) fails to shift anchorage when dragging dangerously close to another anchored vessel. The vessel which anchored first should warn the one who anchored last that the berth chosen will foul the former's berth.

Vessels which drag should take every measure possible to stop dragging, such as dropping a second anchor (MARY FRASER, 26 F 872). Anchored vessels are not required to keep steam up unless weather, ice, or good seamanship demands it. An anchored vessel is not required to take unusual precautions to avoid collisions with moving vessels.

A moored vessel alongside a wharf may be found in fault if she projects into the channel and thereby obstructs it and contributes to a collision. A slight projection may not cause her to be found at fault if passing vessels can pass her safely using reasonable care. If the moored vessel unnecessarily obstructs the slip in which she is secured so that other vessels using the slip cannot evade collision by exercising reasonable care, she may be found at fault. A moored vessel alongside a wharf or slip is not required to show anchor lights, to sound fog signals, or to post a lookout. She must, however, house her anchors in the usual, secure manner so that passing vessels will not be damaged by them. In some areas she may be required by custom or local regulation to show a

white light at each projection or extremity, and normally should of her own accord in congested waters.

Finally, anchorage may be regulated by state or local authorities, provided such ordinances or laws do not conflict with Federal statutes and maritime law as interpreted by U.S. courts.

Stand-by Act—Congress passed the "Stand-by Act" on September 4, 1890. This statute states, in part: "That in every case of collision between two vessels it shall be the duty of the master or person in charge of each vessel, if and so far as he can do so without serious danger to his own vessel, crew and passengers, to stay by the other vessel until he has ascertained that she has no need of further assistance, and to render to the other vessel, her master, crew and passengers such assistance as may be practicable and as may be necessary in order to save them from any danger caused by the collision, and also to give to the master or person in charge of the other vessel the name of his own vessel and her port of registry, or the port or place to which she belongs, and also the name of the ports and places from which and to which she is bound. . . ."

Reports of Collisions—With few exceptions, U.S. vessels which have sustained or caused any accident involving loss of life, material loss of property, or any serious injury to any person, or have received any material damage affecting their seaworthiness or efficiency, are required to report the accident within five days or as soon thereafter as possible to the Commander of the Coast Guard District where the vessel belongs or where the accident took place. (Act June 20, 1874, as amended by Reorganization Plan 3.) This is usually done by means of a written report to the nearest Officer-in-Charge, Marine Inspection.

Exceptions to the foregoing are primarily public vessels, such as Navy and Coast Guard ships, and small vessels numbered by the individual States under the Coast Guard supervised Federal Boating Act of 1958. If numbered by a State, and power-driven, a vessel usually reports directly to the State by which it is numbered (i.e., registered).

Helm Order Act—The Act of Congress of August 21, 1935, has been embodied in the Inland Rules (see Article 32 following). The International Rules, 1960, have no counterpart.

Motor Boat Act of 1940—The Act of April 25, 1940, was a revision of the Act of June 9, 1910. It applies to every vessel in U.S. waters propelled in whole or in part by machinery and not more than 65 feet in length, except tugboats and towboats propelled by steam. In its amended form the Act prescribes lights and sound devices and other safety equipment for such vessels and provides penalties for reckless or negligent operation of any vessel subject to U.S. laws. The Act will be quoted, where pertinent, in a following chapter.

Prior provisions for numbering (i.e., registering) motorboats are superseded by the Federal Boating Act of 1958.

Log Books—The Act of February 27, 1877, as revised, requires that: "Every vessel making voyages from a port in the United States to any foreign port, or, being of the burden of seventy-five tons or upward, from a port on the Atlantic to a port on the Pacific or vice versa, shall have an official log book; and every master of such vessel shall make or cause to be made therein, entries of the following matters, that is to say:

"First. . . .

"Twelfth. In every case of collision in which it is practicable to do so, the master shall, immediately after the occurrence, cause a statement thereof, and of the circumstances under which the same occurred to be entered in the official log book."

Wreck Act, March 3, 1899—The Act empowers the Secretary of the Army to remove any sunken boat, water craft, raft, or other similar obstruction, which has existed for a period longer than thirty days, from any river, lake, harbor, sound, bay, canal, or other navigable waters of the United States.

Death on the High Seas Act, March 30, 1920—The Act permits the personal representative of a decedent to maintain a suit for damages in the District Courts of the United States, in Admiralty, for the exclusive benefit of the decedent's wife, husband, parent, child, or dependent relative against the vessel, person, or corporation which is liable for the wrongful act, neglect, or default resulting in the death of the decedent.

Naval Vessels Lights Act—The Act of September 24, 1963, prescribing the new International Rules of the Road, 1960, and the Acts of March 5, 1948, and December 3, 1945, provide that the several Rules of the Road for International and Inland waters, the Great Lakes, and the Western Rivers shall not apply to any vessel of the Navy or of the Coast Guard, insofar as they pertain to lights, where the Secretary of the Navy, Secretary of the Treasury, or such official or officials as either may designate, shall find or certify that, by reason of special construction, it is not possible with respect to such vessels or class of vessels to comply with the statutory provisions as to the number, position, range of visibility, or arc of visibility of lights. The lights of any such exempt vessel or class of vessel shall, however, comply as closely to the requirements of the statutes as feasible. A notice of such finding or modification and of the character and position of the lights displayed must be published in the Federal Register and in the "Notice to Mariners."

Additional Whistle Signals—Attention is invited to Rule 28(d) of the International Rules, which provides: "Nothing in these Rules shall interfere with the operation of any special rules made by the government of any nation with respect to the use of additional whistle signals between ships of war or vessels sailing under convoy."

This paragraph does not permit a warship or vessel in a convoy to stop the sounding of fog signals in a fog, although war vessels often do, particularly in time of war. It merely legalizes the maneuvering whistle signals which have

been used by naval vessels in formation to indicate or call attention to certain maneuvers.

Sea Manners—The expression is understood by seamen to mean a consideration for the other vessel and the exercise of common sense under certain conditions when vessels meet. A tug with a tow is difficult to maneuver. A large ship is more difficult to maneuver than a smaller one. A convoy or a formation of naval vessels is more difficult to maneuver than a single ship. All of these vessels are required to obey the Rules of the Road. No vessel is exempt. If a vessel disobeys the Rules, she is liable. Accordingly, seamen are not advised to disobey the Rules of the Road to show sea manners, but to obey them. The Rules of the Road apply when there is a risk of collision. Before that moment, there is enough time and plenty of opportunity for a single vessel to avoid a tug with a tow, a convoy, or a formation of naval ships. Small vessels can keep clear of large ones.

New Rule 20(b), International Rules, cautions sailing vessels against hampering large power-driven vessels in narrow channels. New Rule 25(c) prohibits power boats under 65 feet from hindering large vessels navigating a narrow channel. These are but two common cases calling for sea manners. Sea manners should be applied where conditions indicate, and in all waters.

16

Basic Rules, Inland and Ocean Waters

INTERNATIONAL RULES

ACT OF SEPTEMBER 24, 1963

GENERAL PROVISIONS

The President is authorized to proclaim the following regulations . . . for preventing collisions involving waterborne craft upon the high seas, and in all waters connected therewith. The effective date of such proclamation shall be not earlier than the date (*i.e., September 1, 1965*) fixed by the Inter-Governmental Maritime Consultative Organization for application of such regulations by Governments which have agreed to accept them. Such proclamation, together with the regulations, shall be published in the Federal Register and after the effective date specified in such proclamation such regulations shall have effect as if enacted by statute and shall be followed by all public and private vessels of the United States and by all aircraft of United States registry to the extent therein made applicable. Such regulations shall not apply to the harbors, rivers, and other inland waters of the United States; to the Great Lakes of North America and their connecting and tributary waters as far east as the lower exit of the Saint Lambert Lock at Montreal in the Province of Quebec, Canada; to the Red River of the North and the rivers emptying into the Gulf of Mexico and their tributaries; nor

INLAND RULES

ACT OF JUNE 7, 1897

I. ENACTING CLAUSE, SCOPE, AND PENALTY

Whereas the provisions of chapter eight hundred and two of the laws of eighteen hundred and ninety, and the amendments thereto, adopting regulations for preventing collisions at sea [this act was replaced January 1, 1954, by the international rules of left-hand column], apply to all waters of the United States connected with the high seas navigable by seagoing vessels, except so far as the navigation of any harbor, river, or inland waters is regulated by special rules duly made by local authority; and

Whereas it is desirable that the regulations relating to the navigation of all harbors, rivers, and inland waters of the United States, except the Great Lakes and their connecting and tributary waters as far east as Montreal and the Red River of the North and rivers emptying into the Gulf of Mexico and their tributaries, shall be stated in one act: Therefore,

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the following regulations for preventing collisions shall be followed by all vessels upon the harbors, rivers, and other inland waters of the United States, except

INTERNATIONAL RULES

with respect to aircraft in any territorial waters of the United States.

NAVY AND COAST GUARD VESSELS

Any requirement of such regulations in respect of the number, position, range of visibility, or arc of visibility of the lights required to be displayed by vessels shall not apply to any vessel of the Navy or of the Coast Guard whenever the Secretary of the Navy or the Secretary of the Treasury, in the case of Coast Guard vessels operating under the Treasury Department, or such official as either may designate, shall find or certify that, by reason of special construction, it is not possible for such vessel or class of vessels to comply with such regulations. The lights of any such exempted vessel or class of vessels, however, shall conform as closely to the requirements of the applicable regulations as the Secretary or such official shall find or certify to be feasible. Notice of such findings or certification and of the character and position of the lights prescribed to be displayed on such exempted vessel or class of vessels shall be published in the Federal Register and in the Notice to Mariners and, after the effective date specified in such notice, shall have effect as part of such regulations. (Proclaimed effective September 1, 1965.)

REGULATIONS

The regulations authorized to be proclaimed . . . are the Regulations for Preventing Collisions at Sea, 1960, approved by the International Conference on Safety of Life at Sea, 1960, held at London from May 17, 1960, to June 17, 1960, . . . (Pub.L. 88–131, Sept. 24, 1963, 77 Stat. 194, 195). . . .

INLAND RULES

the Great Lakes and their connecting and tributary waters as far east as Montreal, and the waters of the Mississippi River between its source and the Huey P. Long Bridge and all of its tributaries emptying thereinto and their tributaries, and that part of the Atchafalaya River above its junction with the Plaquemine-Morgan City alternate waterway, and the Red River of the North; and are hereby declared special rules duly made by local authority.

SEC. 2. (*a*) *The Secretary of the Department in which the Coast Guard is operating (i.e., Commandant of) shall establish such rules to be observed, on the waters described in section 1 of this Act, by steam vessels in passing each other and as to the lights and day signals to be carried on such waters by ferryboats, by vessels and craft of all types when in tow of steam vessels or operating by hand power or horsepower or drifting with the current, and by any other vessels not otherwise provided for, not inconsistent with the provisions of this Act, as he from time to time may deem necessary for safety, which rules are hereby declared special rules duly made by local authority. A pamphlet containing such Act and regulations shall be furnished to all vessels and craft subject to this Act. On vessels and craft over sixty-five feet in length the pamphlet shall, where practicable, be kept on board and available for ready reference.*

(*b*) *Except in an emergency, before any rules or any alteration, amendment, or repeal thereof are established by the Secretary under the provisions of this section, the said Secretary shall publish the proposed rules, alterations, amendments, or repeals, and public hearings shall be held with respect thereto on such notice as the Secretary*

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deems reasonable under the circumstances.

Sec. 3. (*a*) *The Secretary of the Department in which the Coast Guard is operating may permit vessels desiring to navigate or operate under bridges constructed over navigable waters of the United States to temporarily lower any lights, day signals, or other navigational means and appliances prescribed or required pursuant to law, rule, or regulation, and, if necessary, may authorize vessels so navigating or operating to depart from the rules to prevent collisions as prescribed by law, rule, or regulation. The Secretary of the Department in which the Coast Guard is operating may also prescribe such special regulations to be observed by vessels so navigating or operating as in his judgment the public safety may require for the prevention of collisions.*

(*b*) *Notice of the regulations to accomplish the purposes of this section shall be published in the Federal Register and in the Notice to Mariners, and after the effective date specified in such notices, such regulations shall have the force of law.*

(*c*) *Any person who navigates or operates a vessel in violation of the regulations established pursuant to this section shall be liable to a penalty not exceeding $500. In addition, any vessel navigated or operated in violation of the regulations established pursuant to this section shall be liable to a penalty of $500, for which sum such vessel may be seized and proceeded against, by way of libel, in the district court of the United States for any district within which such vessel may be found.*

Sec. 4. *Every licensed and unlicensed pilot, engineer, mate, or master of any vessel who violates the provisions of this Act or the regulations established pursuant hereto shall be liable to a penalty of not ex-*

INTERNATIONAL RULES

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ceeding $500, and for all damages sustained by any passenger, in his person or baggage, as a result of such violation: Provided, *That nothing herein shall relieve any vessel, owner, or corporation from any liability incurred by such violation.*

SEC. 5. *Every vessel which is navigated in violation of any of the provisions of this Act or the regulations established pursuant hereto shall be liable to a penalty of $500, one-half to go to the informer, for which sum such vessel may be seized and proceeded against by action in any district court of the United States having jurisdiction of the offense.*

PART A—PRELIMINARY AND DEFINITIONS

Rule 1

(a) These Rules shall be followed by all vessels and seaplanes upon the high seas and in all waters connected therewith navigable by seagoing vessels, except as provided in Rule 30. Where, as a result of their special construction, it is not possible for seaplanes to comply fully with the provisions of Rules specifying the carrying of lights and shapes, these provisions shall be followed as closely as circumstances permit.

Rule 30

Reservation of Rules for Harbours and Inland Navigation

Nothing in these Rules shall interfere with the operation of a special rule duly made by local authority relative to the navigation of any harbour, river, lake, or inland water, including a reserved seaplane area.

PRELIMINARY AND DEFINITIONS

Not in Inland Rules.

Not in Inland Rules.

CIVIL AIR REGULATIONS

Seaplanes are not provided for in either the Inland Rules or Pilot Rules for Inland Waters. Seaplanes on the navigable waters of the United States follow

Civil Air Regulations set forth in 14 CFR Parts 3 and 60. As these regulations conform to the Inland Rules for vessels, they are omitted from this text.

PILOT RULES FOR INLAND WATERS

80.01 General instructions.—The regulations in this part apply to vessels navigating the harbors, rivers, and inland waters of the United States, except the Great Lakes and their connecting and tributary waters as far east as Montreal, the Red River of the North, the Mississippi River and its tributaries above Huey P. Long Bridge, and that part of the Atchafalaya River above its junction with the Plaquemine-Morgan City alternate waterway.

80.13(b) Pamphlet containing pilot rules.—All vessels and craft over 65 feet in length upon the waters described in Section 80.01 shall, where practicable, carry on board and maintain for ready reference copies of the current edition of Coast Guard pamphlet CG–169. Nothing in this section shall require copies of this pamphlet to be carried on board any motorboat as defined by section 1 of the Act of April 25, 1940, as amended (54 Stat. 163; 46 U.S.C. 526).

Boundary Lines of Inland Waters

82.1 General basis and purpose of boundary lines.—By virtue of the authority vested in the Commandant of the Coast Guard under section 101 of Reorganization Plan No. 3 of 1946 (11 F.R. 7875), and section 2 of the act of February 19, 1895, as amended (28 Stat. 672, 33 U.S.C. 151), the regulations in this part are prescribed to establish the lines dividing the high seas from rivers, harbors, and inland waters in accordance with the intent of the statute and to obtain its correct and uniform administration. The waters inshore of the lines described in this part are "inland waters," and upon them the Inland Rules and Pilot Rules made in pursuance thereof apply. The waters outside of the lines described in this part are the high seas and upon them the International Rules apply. The regulations in this part do not apply to the Great Lakes or their connecting and tributary waters.

82.2 General rules for inland waters.—At all buoyed entrances from seaward to bays, sounds, rivers, or other estuaries for which specific lines are not described in this part, the waters inshore of a line approximately parallel with the general trend of the shore, drawn through the outermost buoy or other aid to navigation of any system of aids, are inland waters, and upon them the Inland Rules and Pilot Rules made in pursuance thereof apply, except that Pilot Rules for Western Rivers apply to the Red River of the North, the Mississippi River and its tributaries above Huey P. Long Bridge, and that part of the Atchafalaya River above its junction with the Plaquemine-Morgan City alternate waterway.

Interpretive Rulings—International Rules

85.01–1 Scope.—The regulations in this part are interpretive rulings with respect to the "Rules of the Road" requirements applicable to all public and

private vessels of the United States while upon the high seas and in waters connected therewith when subject to the "International Rules" as set forth in the Act of October 11, 1951 (65 Stat. 406–420; 33 U.S.C. 143–147d).

85.01–5 Assignment of functions.—The Secretary of the Treasury by Treasury Department Orders 120, dated July 31, 1950 (15 F.R. 6521), and 167–17, dated June 25, 1955 (20 F.R. 4976), delegated to the Commandant, United States Coast Guard, authority to prescribe such regulations as necessary to carry out the provisions of any law administered by the Coast Guard. The interpretive rulings in this part are prescribed pursuant to section 3 of the Administrative Procedure Act (5 U.S.C. 1002) and 14 U.S.C. 633 in the Act of August 4, 1949.

Interpretive Rulings—Inland Rules

86.01–1 Scope.—The regulations in this part are interpretive rulings with respect to "Rules of the Road" requirements applicable to all vessels while in the harbors, rivers, and other inland waters of the United States except the Great Lakes and their connecting and tributary waters as far east as Montreal and the waters of the Mississippi River between its source and the Huey P. Long Bridge and all of the tributaries emptying thereinto and their tributaries, and that part of the Atchafalaya River above its junction with the Plaquemine-Morgan City alternate waterway, and the Red River of the North.

86.01–5 Assignment of functions.—The Secretary of the Treasury by Treasury Department Orders 120, dated July 31, 1950 (15 F.R. 6521), and 167–17, dated June 25, 1955 (20 F.R. 4976), delegated to the Commandant, United States Coast Guard, authority to prescribe such regulations as necessary to carry out the provisions of any law administered by the Coast Guard. The interpretive rulings in this part are prescribed pursuant to section 3 of the Administrative Procedure Act (5 U.S.C. 1002) and 14 U.S.C. 633 in the Act of August 4, 1949.

86.01–10 Penalties and violations.—(a) Failure to comply with any laws as interpreted will be considered as a violation of such law and the penalty may be assessed as provided by law.

(b) The reports of violations of the "Rules of the Road," as well as the assessment, collection, mitigation or remission of civil penalties authorized by law, shall be in accordance with 46 CFR 2.50–20 to 2.50–30, inclusive (Subchapter A—Procedures Applicable to the Public).

COMMENT: The boundary line between the high seas and Inland waters for vessels is prescribed by the Commandant of the U.S. Coast Guard.

Where no boundary line is prescribed, the line of demarcation is the shore line.

The boundary line for seaplanes is the line which separates U.S. territorial waters from the high seas.

The two boundary lines are not the same.

Sec. 80.13, Pilot Rules, requires all vessels over 65 feet operating on Inland Waters to carry on board the International Rules, Inland Rules, Pilot Rules for Inland Waters, and other related laws and regulations, as published by the Coast Guard in pamphlet CG-169. Copies dated June 1, 1962, or earlier should be discarded, as they omit the 1960 International Rules.

The Interpretive Rulings are relatively new and should be referred to periodically. A penalty is provided for failure to conform to those applicable to Inland Waters. Existing rulings are printed below applicable Rules in following pages.

INTERNATIONAL RULES

Rule 1(b)

The Rules concerning lights shall be complied with in all weathers from sunset to sunrise, and during such times no other lights shall be exhibited, except such lights as cannot be mistaken for the prescribed lights or impair their visibility or distinctive character, on interfere with the keeping of a proper lookout. The lights prescribed by these Rules may also be exhibited from sunrise to sunset in restricted visibility and in all other circumstances when it is deemed necessary.

INLAND RULES

ART. 1. *The rules concerning lights shall be complied with in all weathers from sunset to sunrise, and during such time no other lights which may be mistaken for the prescribed lights shall be exhibited.*

PILOT RULES

80.14 Lights; time for.—The following rules in this part concerning lights shall be complied with in all weathers from sunset to sunrise.

80.24(c) All floodlights or headlights which may interfere with the proper navigation of an approaching vessel shall be so shielded that the lights will not blind the pilot of such vessel.

80.34 Rule relating to the use of searchlights or other blinding lights.—Flashing the rays of a searchlight or other blinding light onto the bridge or into the pilothouse of any vessel under way is prohibited. Any person who shall flash or cause to be flashed the rays of a blinding light in violation of the above may be proceeded against in accordance with the provisions of R.S. 4450, as amended, looking to the revocation or suspension of his license or certificate.

80.36 Rule prohibiting the carrying of unauthorized lights on vessels.—Any master, or pilot of any vessel who shall authorize or permit the carrying of any light, electric or otherwise, not required by law, that in any way will interfere with distinguishing the signal lights, may be proceeded against in accordance with the provisions of R.S. 4450, as amended, looking to a suspension or revocation of his license.

COMMENT: Lights prescribed by the Rules must be shown from sunset to sunrise in both Inland Waters and on the high seas. Use of such lights at other times is permitted by International Rules.

In Inland Waters, where the Rules are silent on this point, use of such lights between sunrise and sunset could probably be justified by Article 29, Inland Rules, which cautions mariners to take all necessary precautions.

INTERNATIONAL RULES

Rule 1(c)

In the following Rules, except where the context otherwise requires:—

(i) the word "vessel" includes every description of water craft, other than a seaplane on the water, used or capable of being used as a means of transportation on water;

(ii) the word "seaplane" includes a flying boat and any other aircraft designed to manoeuvre on the water;

(iii) the term "power-driven vessel" means any vessel propelled by machinery;

(iv) every power-driven vessel which is under sail and not under power is to be considered a sailing vessel, and every vessel under power, whether under sail or not, is to be considered a power-driven vessel;

(v) a vessel or seaplane on the water is "under way" when she is not at anchor, or made fast to the shore, or aground;

(vi) the term "height above the hull" means height above the uppermost continuous deck;

(vii) the length and breadth of a vessel shall be her length overall and largest breadth;

(viii) the length and span of a seaplane shall be its maximum length and span as shown in its certificate of airworthiness, or as determined by measurement in the absence of such certificate;

(ix) vessels shall be deemed to be in sight of one another only when one can be observed visually from the other;

INLAND RULES

Not in Inland Rules.

Not in Inland Rules.

Preliminary Definitions

The words "steam vessel" shall include any vessel propelled by machinery.

In the following rules every steam vessel which is under sail and not under steam is to be considered a sailing vessel, and every vessel under steam, whether under sail or not, is to be considered a steam vessel.

A vessel is "under way," within the meaning of these rules, when she is not at anchor, or made fast to the shore, or aground.

Not in Inland Rules.

ART. 11. *The length of a vessel shall be deemed to be the length appearing in her certificate of registry.*

Not in Inland Rules.

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	II. LIGHTS, AND SO FORTH
(x) the word "visible," when applied to lights, means visible on a dark night with a clear atmosphere;	*The word "visible" in these rules, when applied to lights, shall mean visible on a dark night with a clear atmosphere.*
(xi) the term "short blast" means a blast of about one second's duration;	*Not in Inland Rules.*
(xii) the term "prolonged blast" means a blast of from four to six seconds' duration;	ART. 15. *The words "prolonged blast" used in this article shall mean a blast of from four to six seconds' duration.*
(xiii) the word "whistle" means any appliance capable of producing the prescribed short and prolonged blasts;	*Not in Inland Rules.*
(xiv) the term "engaged in fishing" means fishing with nets, lines or trawls but does not include fishing with trolling lines.	*Not in Inland Rules.*

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80.02 Definition of steam vessel and vessel under way; risk of collision.—In the rules in this part the words "steam vessel" shall include any vessel propelled by machinery. A vessel is under way, within the meaning of the rules in this part, when she is not at anchor, or made fast to the shore, or aground. Risk of collision can, when circumstances permit, be ascertained by carefully watching the compass bearing of an approaching vessel. If the bearing does not appreciably change, such risk should be deemed to exist.

80.24 Lights generally.—(a) All the lights required by §§ 80.18 to 80.23, inclusive, except as provided in §§ 80.18(b) and 80.21(b), shall be of such character as to be visible on a dark night with a clear atmosphere for a distance of at least two miles.

(b) The lights required by § 80.18(b) to be of the same character as the regular towing lights and the lights required by § 80.21(b) to be of the same character as the masthead light shall be of such character as to be visible on a dark night with a clear atmosphere for a distance of at least five miles.

80.03 Signals.—(a) The whistle signals provided in the rules in this part shall be sounded on an efficient whistle or siren sounded by steam or by some substitute for steam.

(1) A short blast of the whistle shall mean a blast of about one second's duration.

(2) A prolonged blast of the whistle shall mean a blast of from 4 to 6 seconds' duration.

COMMENT: A vessel is under way, among other conditions, when it is not secured to a buoy or when its anchor is aweigh. She is also under way when one anchor has been dropped "underfoot" to assist in maneuvering. (CITY OF ERIE, 250 F 259.) A vessel is liable if she anchors so suddenly in the path of a following vessel that collision cannot be avoided. (SOSUA, 271 F 772.) "A sailing vessel lying to in a fog, but having some of her sails up, is under way." (BURROWS *v.* GOWER, 119 F 616.)

A steam vessel (power-driven), motionless in the water, is under way. (NIMROD, 173 F 520.) A vessel drifting is also under way. (NYC, NO 18, 230 F 299.) A vessel in tow is also under way. (JOAQUIN MUMBRU—SCANDINAVIA, 11 F 2d, 542.)

Note that the definition of a vessel, under International Rule 1(c) (1) above, excepts the "seaplane on the water" and that, under International Rule 18(b), following, a seaplane on the water is deemed to be a vessel for the particular purposes of Rules 18–29 inclusive, i.e., for meeting, crossing, overtaking and narrow channel cases.

Notice, also, that "whistle," as defined in International Rules, means any appliance capable of making the prescribed short or prolonged blasts. This definition will affect blowing fog signals, as given in Rule 15(b), and changes of course (see Rule 28).

17

Lights and Shapes of Identification, Rules (Articles) 2–6

INTERNATIONAL RULES

PART B—LIGHTS AND SHAPES

Rule 2 (Fig. 17.1)

(a) A power-driven vessel when under way shall carry:

(i) On or in front of the foremast, or if a vessel without a foremast then in the forepart of the vessel, a white light so constructed as to show an unbroken light over an arc of the horizon of 225 degrees (20 points of the compass), so fixed as to show the light 112½ degrees (10 points) on each side of the vessel, that is, from right ahead to 22½ degrees (2 points) abaft the beam on either side, and of such a character as to be visible at a distance of at least 5 miles.

INLAND RULES

II. LIGHTS, AND SO FORTH

ART. 2. *A steam vessel when under way shall carry—(a) On or in the front of the foremast, or if a vessel without a foremast, then in the forepart of the vessel, a bright white light so constructed as to show an unbroken light over an arc of the horizon of twenty points of the compass, so fixed as to throw the light ten points on each side of the vessel, namely, from right ahead to two points abaft the beam on either side, and of such a character as to be visible at a distance of at least five miles.*

FIG. 17.1 STEAMER WITH RANGE LIGHTS

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(ii) Either forward of abaft the white light prescribed in sub-section (i) a second white light similar in construction and character to that light. Vessels of less than 150 feet in length shall not be required to carry this second white light but may do so.

(iii) These two white lights shall be so placed in a line with and over the keel that one shall be at least 15 feet higher than the other and in such a position that the forward light shall always be shown lower than the after one. The horizontal distance between the two white lights shall be at least three times the vertical distance. The lower of these two white lights or, if only one is carried, then that light, shall be placed at a height above the hull of not less than 20 feet, and, if the breadth of the vessel exceeds 20 feet, then at a height above the hull not less than such breadth, so however that the light need not be placed at a greater height above the hull than 40 feet. In all circumstances the light or lights, as the case may be, shall be so placed as to be clear of and above all other lights and obstructing superstructures.

(iv) On the starboard side a green light so constructed as to show an unbroken light over an arc of the horizon of 112½ degrees (10 points of the compass), so fixed as to show the light from right ahead to 22½ degrees (2 points) abaft the beam on the starboard side, and of such a character as to be visible at a distance of at least 2 miles.

(v) On the port side a red light so constructed as to show an unbroken light over an arc of the horizon of 112½ degrees (10 points of

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(e) A seagoing steam vessel when under way may carry an additional white light similar in construction to the light mentioned in subdivision (a). These two lights shall be so placed in line with the keel that one shall be at least fifteen feet higher than the other, and in such a position with reference to each other that the lower light shall be forward of the upper one. The vertical distance between these lights shall be less than the horizontal distance.

(f) All steam vessels (except seagoing vessels and ferryboats), shall carry in addition to green and red lights required by article 2 (b), (c), and screens as required by article 2 (d), a central range of two white lights; the after light being carried at an elevation at least fifteen feet above the light at the head of the vessel. The headlight shall be so constructed as to show an unbroken light through twenty points of the compass, namely, from right ahead to two points abaft the beam on either side of the vessel, and the after light so as to show all around the horizon.

(b) On the starboard side a green light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the starboard side, and of such a character as to be visible at a distance of at least two miles.

(c) On the port side a red light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so

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the compass), so fixed as to show the light from right ahead to 22½ degrees (2 points) abaft the beam on the port side, and of such a character as to be visible at a distance of at least 2 miles.

(vi) The said green and red sidelights shall be fitted with inboard screens projecting at least 3 feet forward from the light, so as to prevent these lights from being seen across the bows.

(b) A seaplane under way on the water shall carry:

(i) In the forepart amidships where it can best be seen a white light, so constructed as to show an unbroken light over an arc of the horizon of 220 degrees of the compass, so fixed as to show the light 110 degrees on each side of the seaplane, namely, from right ahead to 20 degrees abaft the beam on either side, and of such a character as to be visible at a distance of at least 3 miles.

(ii) On the right or starboard wing tip a green light, so constructed as to show an unbroken light over an arc of the horizon of 110 degrees of the compass, so fixed as to show the light from right ahead to 20 degrees abaft the beam on the starboard side, and of such a character as to be visible at a distance of at least 2 miles.

(iii) On the left or port wing tip a red light, so constructed as to show an unbroken light over an arc of the horizon of 110 degrees of the compass, so fixed as to show the light from right ahead to 20 degrees abaft the beam on the port side, and of such a character as to be visible at a distance of at least 2 miles.

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fixed as to throw the light from right ahead to two points abaft the beam on the port side, and of such a character as to be visible at a distance of at least two miles.

(d) The said green and red side lights shall be fitted with inboard screens projecting at least three feet forward from the light, so as to prevent these lights from being seen across the bow.

Not in Inland Rules.

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80.15 Ferryboats.—(a) Ferryboats propelled by machinery and navigating the harbors, rivers, and other inland waters of the United States, except the

Great Lakes and their connecting and tributary waters as far east as Montreal, the Red River of the North, the Mississippi River and its tributaries above Huey P. Long Bridge, and that part of the Atchafalaya River above its junction with the Plaquemine-Morgan City alternate waterway, shall carry the range lights and the colored side lights required by law to be carried on steam vessels navigating those waters, except that double-end ferryboats shall carry a central range of clear, bright, white lights, showing all around the horizon, placed at equal altitudes forward and aft, also on the starboard side a green light, and on the port side a red light, of such a character as to be visible on a dark night with a clear atmosphere at a distance of at least 2 miles, and so constructed as to show a uniform and unbroken light over an arc of the horizon of 10 points of the compass, and so fixed as to throw the light from right ahead to 2 points abaft the beam on their respective sides.

(b) The green and red lights shall be fitted with inboard screens projecting at least 3 feet forward from the lights, so as to prevent them from being seen across the bow.

(c) Officers in Charge, Marine Inspection, in districts having ferryboats shall, whenever the safety of navigation may require, designate for each line of such boats a certain light, white or colored, which will show all around the horizon, to designate and distinguish such lines from each other, which light shall be carried on a flagstaff amidships, 15 feet above the white range lights.

Comment: Power-driven vessels, 150 feet and more in length, are required by the International Rules to carry a 20-point, white range light, forward and below *or* abaft and above the masthead light. The Inland Rules require an additional white light, too, for all steam vessels except seagoing vessels and ferryboats. It must be an all-around white light. Seagoing vessels under Inland Rules may carry a 20-point range light and normally do, due to International Rule 2(a). Ferryboat lights are based on whether they are single- or double-ended.

The International and Inland Rules require the masthead and range lights to be placed "in line with and over the keel." This is not possible on aircraft carriers. The enacting provisions of the International Rules (Chapter 16) provide for the variation, as does the Act of December 3, 1945, as amended, which is similar, in Inland Waters.

The International Rules require the lower of the two range lights to be placed at a prescribed height above the hull. The Inland Rules do not prescribe the height.

Many vessels have been found "in fault" by the Courts because the side lights were

1. Not installed according to the Rules.
2. Not burning brightly.
3. Obscured.
4. Out.

The officer in charge of a vessel under way should require inspections and reports of the side, masthead, range, and stern lights to be made at regular (half-hour) intervals. He would be wise to inspect these lights himself frequently. If the vessel is not equipped with alternate, electrical side lights, he should require oil side lights to be cleaned, trimmed, lighted and ready on deck to replace the electrical ones without delay if necessary.

Under both Rules, the white range lights must be visible for 5 miles and the colored side lights, for 2 miles. White lights can be seen farther than colored lights. These two factors mean that the range lights are "picked up" more easily and quickly than the side lights. This is fortunate because the range lights give a more accurate estimate of the course of the approaching vessel than side lights.

Single-ended ferryboats are not encountered as frequently as double-ended ones. Single-ended ones carry the usual navigation lights, side lights, and two range lights. The double-ended ones, when in Inland Waters, carry a range of two all-around white lights at equal heights in addition to side lights. Thus the masthead light is replaced by an all-around light, and the after range light is at the same height above the hull as the forward one.

An occasional line of ferryboats is seen in Inland Waters, the boats of which carry a distinguishing light between and above the two white range lights.

The International Rules require each of the side lights of a seaplane to be visible through 110 degrees; this is true also of the Civil Air Regulations. The International Rules require a visibility of 2 miles for side lights; the Civil Air Regulations do not prescribe the visibility distance.

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Rule 3 (Figs. 17.2 and 17.3)

(a) A power-driven vessel when towing or pushing another vessel or seaplane shall, in addition to her sidelights, carry two white lights in a vertical line one over the other, not less than 6 feet apart, and when towing and the length of the tow, measuring from the stern of the towing vessel to the stern of the last vessel towed, exceeds 600 feet, shall carry three white lights in a vertical line one over the other, so that the upper and lower lights shall be the same distance from, and not less than 6 feet above or below, the middle light. Each of these lights shall be of the same construction and character and one of them shall be carried in the same position as the white light prescribed in Rule 2(a)

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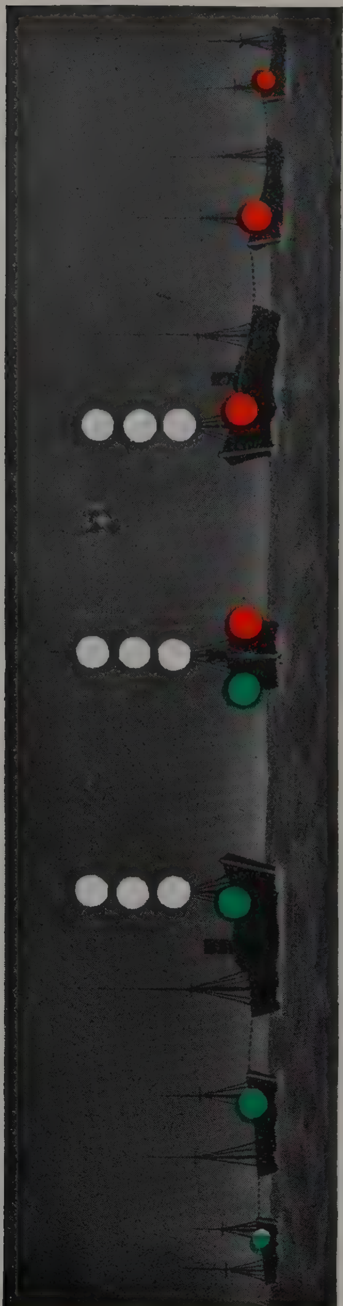
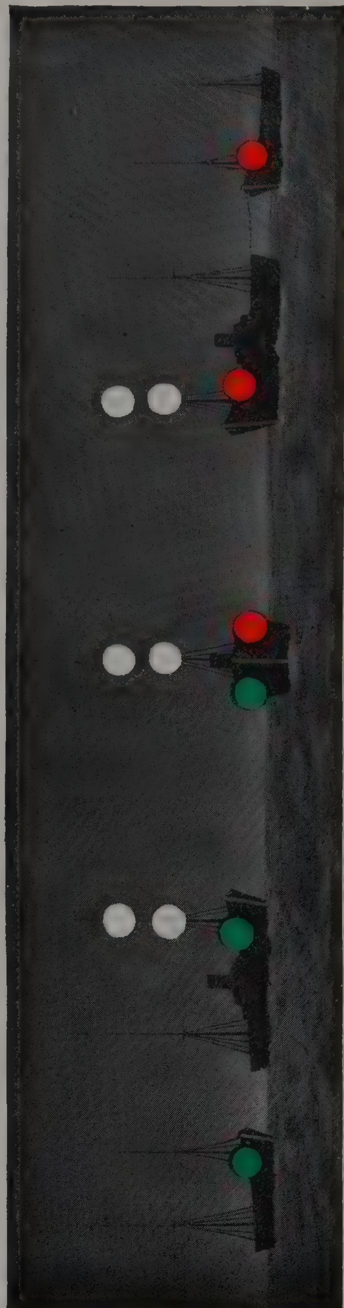
(Figs. 17.2 and 17.3)

ART. 3. (*a*) *A steam vessel when towing another vessel or vessels alongside or by pushing ahead shall, in addition to her side lights, carry two bright white lights in a vertical line, one over the other, not less than three feet apart, and when towing one or more vessels astern, regardless of the length of the tow, shall carry an additional bright white light three feet above or below such lights. Each of these lights shall be of the same construction and character, and shall be carried in the same position as the white light mentioned in article 2* (*a*) *or the after range light mentioned in article 2* (*f*).



INTERNATIONAL

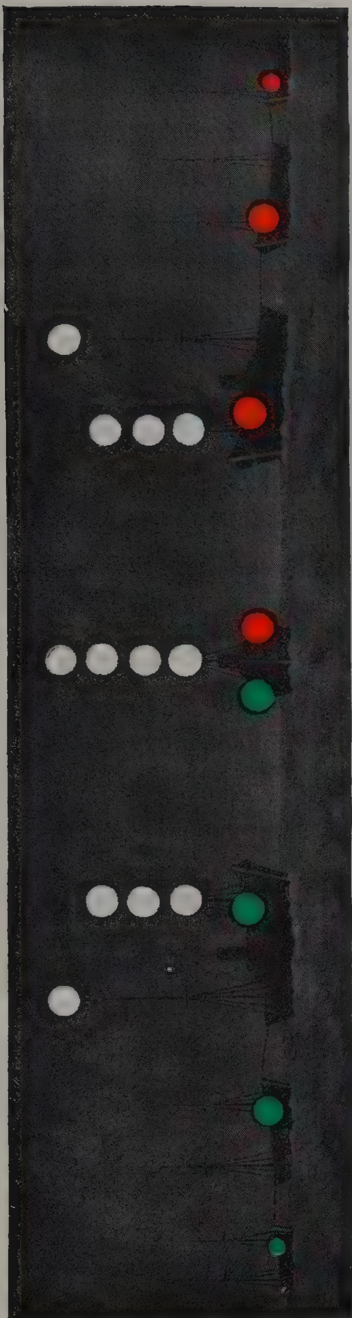
Towing (length of tow exceeding 600 feet)



INTERNATIONAL

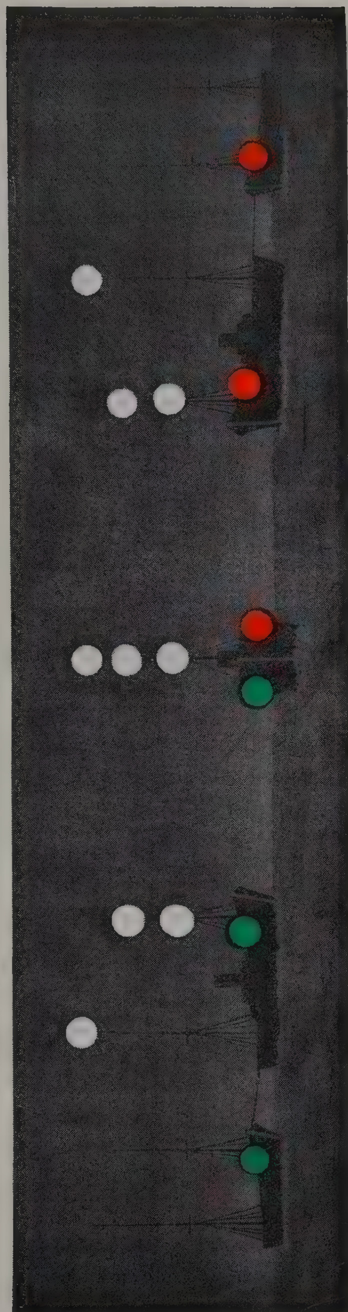
Towing (length of tow not exceeding 600 feet)

FIG. 17.2 STEAMER TOWING WITHOUT RANGE LIGHTS



INTERNATIONAL AND INLAND

International: Towing (length of tow exceeding 600 feet). Inland: Towing one or more vessels (tow any length)



INTERNATIONAL

Towing (length not exceeding 600 feet)

FIG. 17.3 STEAMER TOWING WITH RANGE LIGHTS

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(i). None of these lights shall be carried at a height of less than 14 feet above the hull. In a vessel with a single mast, such lights may be carried on the mast.

(b) The towing vessel shall also show either the stern light prescribed in Rule 10 or in lieu of that light a small white light abaft the funnel or aftermast for the tow to steer by, but such light shall not be visible forward of the beam.

(c) Between sunrise and sunset a power-driven vessel engaged in towing, if the length of tow exceeds 600 feet, shall carry, where it can best be seen, a black diamond shape at least 2 feet in diameter.

(d) A seaplane on the water, when towing one or more seaplanes or vessels, shall carry the lights prescribed

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(*b*) *A steam vessel carrying towing lights the same as the white light mentioned in article 2* (*a*), *when pushing another vessel or vessels ahead, shall also carry at or near the stern two bright amber lights in a vertical line, one over the other, not less than three feet apart; each of these lights shall be so constructed as to show an unbroken light over an arc of the horizon of twelve points of the compass, so fixed as to show the light six points from right aft on each side of the vessel, and of such a character as to be visible at a distance of at least two miles. A steam vessel carrying towing lights the same as the white light mentioned in article 2* (*a*) *may also carry, irrespective of the position of the tow, the after range light mentioned in article 2* (*f*)*; however, if the after range light is carried by such a vessel when pushing another vessel or vessels ahead, the amber lights shall be carried in a vertical line with and at least three feet lower than the after range light. A steam vessel carrying towing lights the same as the white light mentioned in article 2* (*a*), *when towing one or more vessels astern, may also carry, in lieu of the stern light specified in article 10, a small white light abaft the funnel or aftermast for the tow to steer by, but such light shall not be visible forward of the beam.*

Not in Inland Rules.

Not in Inland Rules.

INTERNATIONAL RULES

INLAND RULES

in Rule 2(b) (i), (ii) and (iii); and, in addition, she shall carry a second white light of the same construction and character as the white light prescribed in Rule 2(b) (i), and in a vertical line at least 6 feet above or below such light.

PILOT RULES

80.18 Signals to be displayed by a towing vessel when towing a submerged or partly submerged object upon a hawser when no signals can be displayed upon the object which is towed.—(a) The vessel having the submerged object in tow shall display by day, where they can best be seen, two shapes, one above the other, not less than six feet apart, the lower shape to be carried not less than 10 feet above the deck house. The shapes shall be in the form of a double frustum of a cone, base to base, not less than two feet in diameter at the center nor less than eight inches at the ends of the cones, and to be not less than four feet lengthwise from end to end, the upper shape to be painted in alternate horizontal stripes of black and white, eight inches in width, and the lower shape to be painted a solid bright red.

(b) By night the towing vessel shall display the regular side lights but in lieu of the regular white towing lights shall display four lights in a vertical position not less than three feet nor more than six feet apart, the upper and lower of such lights to be white, and the two middle lights to be red, all of such lights to be of the same character as the regular towing lights.

NOTE: The regulations in §§ 80.18 to 80.31a are applicable on the harbors, rivers, and inland waters along the Atlantic and Pacific Coasts and the Coast of the Gulf of Mexico, as described in § 80.01. Similar regulations . . . are applicable on the "western rivers." . . . Similar Department of the Army (Corps of Engineers) regulations . . . are applicable on the Great Lakes and their connecting and tributary waters as far east as Montreal. . . .

COMMENT: The International Rules do not mention towing alongside. Towing lights are carried by all steam- or power-driven vessels when towing. Sailing vessels, towing, show side lights only, plus a stern light. Towing lights are not required. Under International Rules, however, a sailing vessel towing, like any sailing vessel under way, may show a red light over a green light from the foremast (Rule 5).

The towing lights are at least six feet apart under the International Rules and not less than 3 feet in the Inland Rules.

One of the towing lights is carried in the same position as the masthead light on the high seas. In Inland Waters, the towing lights may be carried in one of two positions:

(a) in place of the masthead light, in which case they are 20-point lights;

(b) in place of the after range light where they are all-around lights.

A masthead light is not required in Inland Waters if the towing lights are

aft. A range light is not required but may be carried if the towing lights are forward. In International Waters, reference to the after range light has been deleted from the 1960 Rules, leaving the implication that this light is optional for towing vessels of less than 150 feet and mandatory for vessels of 150 feet upwards.

The 1960 International Rules require a third towing light only when towing astern and the length of the tow exceeds 600 feet. The Inland Rules require three towing lights when towing one or more vessels astern regardless of the length of the tow.

The towing vessel must show either a stern light or a white steering light aft in International Waters. In Inland Waters the towing vessel must show two 12-point amber lights visible from aft when pushing, if she is carrying 20-point towing lights. If towing astern with 20-point lights, she may show a white steering light or stern light aft or carry the all around after range light. Other towing vessels Inland may carry either the stern light or the all around after-range light or may omit both lights, depending on the arc of the towing lights. Note that the amber light requirement in Inland Rules took effect August 14, 1958. Its purpose is to inform overtaking vessels that the vessel ahead is pushing a tow.

A tug with a tow might show an approaching vessel a variety of white lights, depending upon the following factors:

1. High seas or Inland waters.
2. Number of vessels in tow.
3. Length of the towline.
4. Bearing of approaching vessel.
5. Location of towing lights.

COURT DECISION: If the tow is manned, she is responsible that the proper lights on the tow are shown. The tug is responsible for her own lights and jointly for those on the tow. (EUGENE F. MORAN, 212 U.S. 466.) If the tow has no crew, the tug is responsible for showing proper lights on the tow. (LIZZIE M. WALKER, C.C.A.4, 3F Supp. 921.)

INTERNATIONAL RULES	*INLAND RULES*
Rule 4 (Figs. 17.4 to 17.6)	
(a) A vessel which is not under command shall carry, where they can best be seen, and, if a power-driven vessel, in lieu of the lights prescribed in Rule 2(a) (i) and (ii), two red lights in a vertical line one over the other not less than 6 feet apart, and of such a character as to be visible all round the horizon at a distance of at least 2 miles. By day, she shall	*Not in Inland Rules.*

INTERNATIONAL RULES | *INLAND RULES*

carry in a vertical line one over the other not less than 6 feet apart, where they can best be seen, two black balls or shapes each not less than 2 feet in diameter.

(b) A seaplane on the water which is not under command may carry,

INTERNATIONAL

Carries Side Lights, if Making Way Through Water

VESSEL NOT UNDER COMMAND

Carries Side Lights, if Making Way Through Water

VESSEL WORKING WITH TELEGRAPH CABLE

FIG. 17.4 DAY MARKS AND LIGHTS. FISHING AND CABLE VESSELS

where they can best be seen, and in lieu of the light prescribed in Rule 2(b) (i), two red lights in a vertical line, one over the other, not less than 3 feet apart, and of such a character as to be visible all round the horizon at a distance of at least 2 miles, and may by day carry in a vertical line one over the other not less than 3 feet apart, where they

INTERNATIONAL RULES

can best be seen two black balls or shapes, each not less than 2 feet in diameter.

(c) A vessel engaged in laying or in picking up a submarine cable or navigation mark, or a vessel engaged in surveying or underwater operations, or a vessel engaged in replenishment at sea, or in launching or recovery of aircraft when from the nature of her work she is unable to get out of the way of approaching vessels, shall carry, in lieu of the lights prescribed in Rule 2(a) (i) and (ii), or Rule 7(a) (i) three lights in a vertical line one over the other so that the upper and lower lights shall be the same distance from, and not less than 6 feet above or below, the middle light. The highest and lowest of these lights shall be red, and the middle light shall be white, and they shall be of such a character as to be visible all round the horizon at a distance of at least 2 miles. By day, she shall carry in a vertical line one over the other not less than 6 feet apart, where they can best be seen, three shapes each not less than 2 feet in diameter, of which the highest and lowest shall be globular in shape and red in colour, and the middle one diamond in shape and white.

(d) (i) A vessel engaged in minesweeping operations shall carry at the fore truck a green light, and at the end or ends of the fore yard on the side or sides on which danger exists, another such light or lights. These lights shall be carried in addition to the light prescribed in Rule 2(a) (i) or Rule 7(a) (i), as appropriate, and shall be of such character as to be visible all round the horizon at a distance of at least 2 miles. By day she shall carry black balls, not less than 2 feet in diameter, in the same position as the green lights.

(ii) The showing of these lights

INLAND RULES

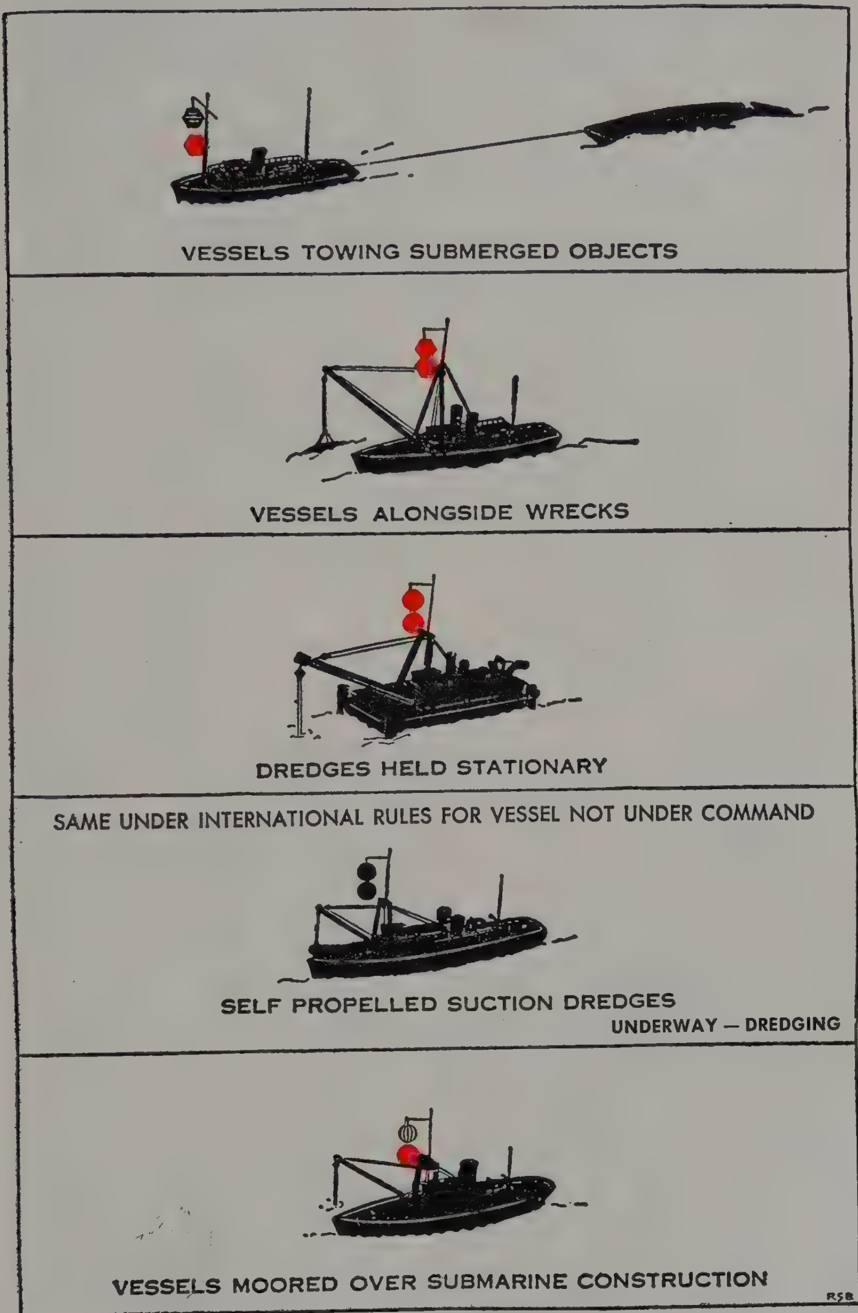


FIG. 17.5 DAY MARKS. Applicable to Inland Waters

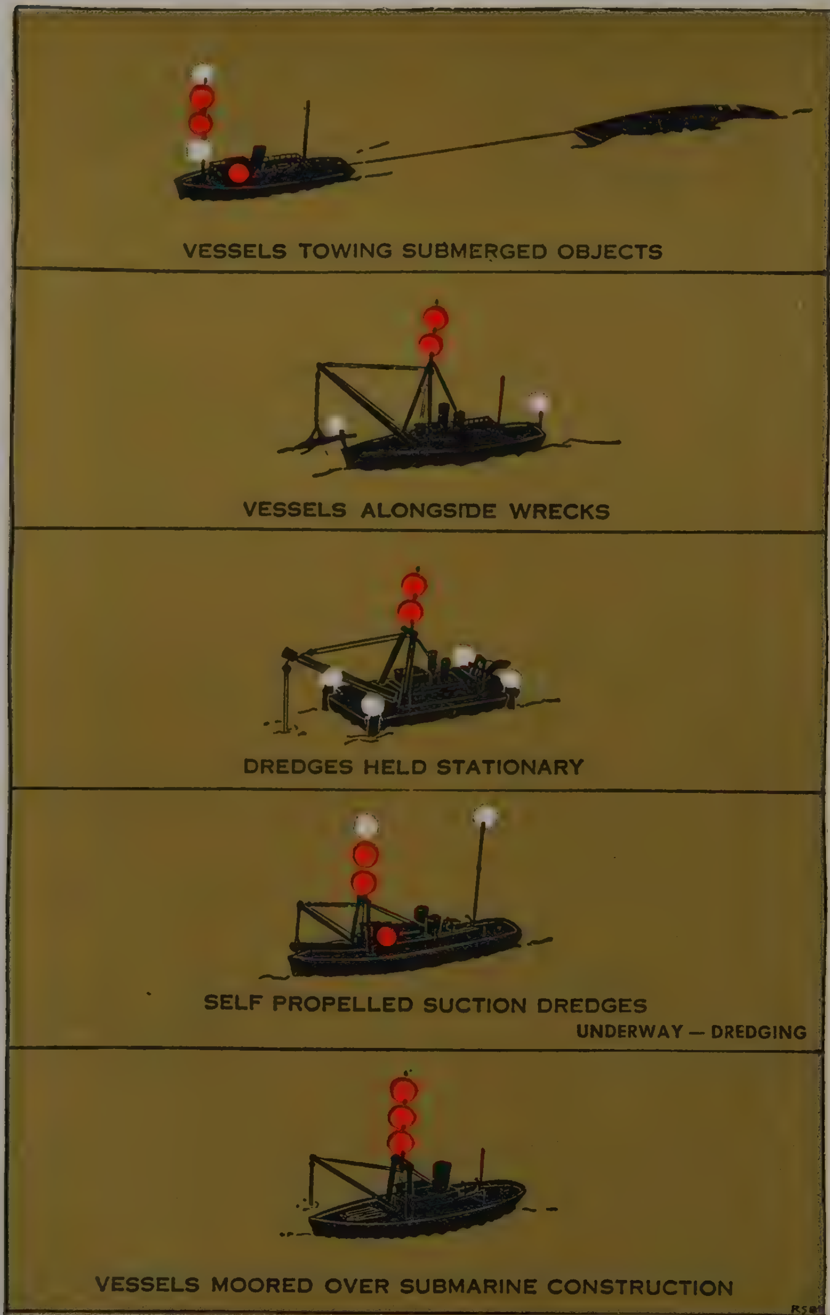


FIG. 17.6 LIGHTS ON VESSELS. Applicable to Inland Waters

INTERNATIONAL RULES

or balls indicates that it is dangerous for other vessels to approach closer than 3,000 feet astern of the minesweeper or 1,500 feet on the side or sides on which danger exists.

(e) The vessels and seaplanes referred to in this Rule, when not making way through the water, shall show neither the coloured sidelights nor the stern light, but when making way they shall show them.

(f) The lights and shapes prescribed in this Rule are to be taken by other vessels and seaplanes as signals that the vessel or seaplane showing them is not under command and cannot therefore get out of the way.

(g) These signals are not signals of vessels in distress and requiring assistance. Such signals are contained in Rule 31.

INLAND RULES

PILOT RULES

80.19 Steam vessels, derrick boats, lighters, or other types of vessels made fast alongside a wreck, or moored over a wreck which is on the bottom or partly submerged, or which may be drifting.—(a) Steam vessels, derrick boats, lighters, or other types of vessels made fast alongside a wreck, or moored over a wreck which is on the bottom or partly submerged, or which may be drifting, shall display by day two shapes of the same character and dimensions and displayed in the same manner as required by § 80.18(a), except that both shapes shall be painted a solid bright red, but where more than one vessel is working under the above conditions, the shapes need be displayed only from one vessel on each side of the wreck from which they can best be seen from all directions.

(b) By night this situation shall be indicated by the display of a white light from the bow and stern of each outside vessel or lighter not less than six feet above the deck, and in addition thereto there shall be displayed in a position where they can best be seen from all directions two red lights carried in a vertical line not less than three feet nor more than six feet apart, and not less than 15 feet above the deck.

80.20 Dredges held in stationary position by moorings or spuds.—(a) Dredges which are held in stationary position by moorings or spuds shall display by day two red balls not less than two feet in diameter and carried in a vertical line not less than three feet nor more than six feet apart, and at least

15 feet above the deck house and in such a position where they can best be seen from all directions.

(b) By night they shall display a white light at each corner, not less than six feet above the deck, and in addition thereto there shall be displayed in a position where they can best be seen from all directions two red lights carried in a vertical line not less than three feet nor more than six feet apart, and not less than 15 feet above the deck. When scows are moored alongside a dredge in the foregoing situation they shall display a white light on each outboard corner, not less than six feet above the deck.

80.21 Dredges under way and engaged in dredging operations.—(a) Dredges under way and engaged in dredging operations shall display by day two black balls not less than two feet in diameter and carried in a vertical line not less than three feet nor more than six feet apart, where they can best be seen from all directions. The term "dredging operations" shall include maneuvering into or out of position at the dredging site but shall not include proceeding to or from the site.

(b) By night, self-propelled dredges under way and engaged in dredging operations shall carry, in addition to the regular running lights, two red lights of the same character as the white masthead light, in a vertical line beneath that light. These red lights shall be not less than three feet nor more than six feet apart and the upper red light shall be not less than three feet nor more than six feet below the masthead light. They shall also carry on or near the stern two red lights in a vertical line not less than three feet nor more than six feet apart, to show through twelve points of the compass; that is, from right astern to six points on each quarter.

(c) By night, a non-self-propelled dredge which is under way and engaged in dredging operations while being pushed ahead by a towboat shall be considered, with such towboat, for the purpose of compliance with Rules of the Road requirements for lights and shapes, as a single vessel. This vessel shall carry the lights described in paragraph (b) of this section, except that both the dredge and towboat shall carry the sidelights normally required for a barge towed by being pushed ahead and a vessel towing, respectively. When not engaged in dredging operations, this unit shall carry the regular lights for vessels towing and being towed.

80.22 Vessels moored or anchored and engaged in laying cables or pipe, submarine construction, excavation, mat sinking, bank grading, dike construction, revetment, or other bank protection operations.—(a) Vessels which are moored or anchored and engaged in laying cables or pipe, submarine construction, excavation, mat sinking, bank grading, dike construction, revetment, or other bank protection operations, shall display by day, not less than 15 feet above the deck, where they can best be seen from all directions, two balls not less than two feet in diameter, in a vertical line not less than three feet nor more than six feet apart, the upper ball to be painted in

alternate black and white vertical stripes six inches wide, and the lower ball to be painted a solid bright red.

(b) By night they shall display three red lights, carried in a vertical line not less than three feet nor more than six feet apart, in a position where they can best be seen from all directions, with the lowermost light not less than 15 feet above the deck.

(c) Where a stringout of moored vessels or barges is engaged in the operations, three red lights carried as prescribed in paragraph (b) of this section shall be displayed at the channelward end of the stringout. Where the stringout crosses the navigable channel and is to be opened for the passage of vessels, the three red lights shall be displayed at each side of the opening instead of at the outer end of the stringout. There shall also be displayed upon such stringout one horizontal row of amber lights not less than six feet above the deck, or above the deck house where the craft carries a deck house, in a position where they can best be seen from all directions, spaced not more than 50 feet apart so as to mark distinctly the entire length and course of the stringout.

80.23 Lights to be displayed on pipe lines.—Pipe lines attached to dredges, and either floating or supported on trestles, shall display by night one row of amber lights not less than 8 feet nor more than 12 feet above the water, about equally spaced and in such number as to mark distinctly the entire length and course of the line, the intervals between lights where the line crosses navigable channels to be not more than 30 feet. There shall also be displayed on the shore or discharge end of the line two red lights, three feet apart, in a vertical line with the lower light at least eight feet above the water, and if the line is to be opened at night for the passage of vessels, a similar arrangement of lights shall be displayed on each side of the opening.

80.24 Lights generally.—(a) All the lights required by §§ 80.18 to 80.23, inclusive, except as provided in §§ 80.18(b) and 80.21(b), shall be of such character as to be visible on a dark night with a clear atmosphere for a distance of at least two miles.

(b) The lights required by § 80.18(b) to be of the same character as the regular towing lights and the lights required by § 80.21(b) to be of the same character as the masthead light shall be of such character as to be visible on a dark night with a clear atmosphere for a distance of at least five miles.

(c) All floodlights or headlights which may interfere with the proper navigation of an approaching vessel shall be so shielded that the lights will not blind the pilot of such vessel.

80.29 Aids to navigation marking floating-plant moorings.—Breast, stern, and bow anchors of floating plant working in navigable channels shall be marked by barrel or other suitable buoys. By night approaching vessels shall be shown the location of adjacent buoys by throwing a suitable beam of light from the plant on the buoys until the approaching vessel has passed, or the buoys may be lighted by red lights, visible in all directions, of the same character as specified in § 80.24(a): *Provided,* That the foregoing provisions

of this section shall not apply to the following waters of New York Harbor and adjacent waters: the East River, the North River (Battery to Spuyten Duyvil), the Harlem River and the New York and New Jersey Channels (from the Upper Bay through Kill Van Kull, Newark Bay, Arthur Kill, and Raritan Bay to the Lower Bay).

80.30 Obstruction of channel by floating plant.—Channels shall not be obstructed unnecessarily by any dredge or other floating plant. While vessels are passing such plant, all lines running therefrom across the channel on the passing side, which may interfere with or obstruct navigation, shall be slacked to the bottom of the channel.

80.31 Clearing of channels.—When special or temporary regulations have not been prescribed and action under the regulations contained in §§ 80.26 to 80.30, inclusive, will not afford clear passage, floating plants in narrow channels shall, upon notice, move out of the way of vessels a sufficient distance to allow them a clear passage. Vessels desiring passage shall, however, give the master of the floating plant ample notice in advance of the time they expect to pass.

NOTE: If it is necessary to prohibit or limit the anchorage or movement of vessels within certain areas in order to facilitate the work of improvement, application should be made through official channels for establishment by the Secretary of the Army of special or temporary regulations for this purpose.

80.31a Protection of marks placed for the guidance of floating plant.—Vessels shall not run over anchor buoys, or buoys, stakes, or other marks placed for the guidance of floating plants working in channels; and shall not anchor on the ranges of buoys, stakes, or other marks placed for the guidance of such plant.

80.33 Special signals for vessels employed in hydrographic surveying.—By day a surveying vessel of the Coast and Geodetic Survey, under way and employed in hydrographic surveying, may carry in a vertical line, one over the other not less than 6 feet apart where they can best be seen, three shapes not less than 2 feet in diameter of which the highest and lowest shall be globular in shape and green in color and the middle one diamond in shape and white.

(a) Vessels of the Coast and Geodetic Survey shall carry the above-prescribed marks while actually engaged in hydrographic surveying and under way, including drag work. Launches and other boats shall carry the prescribed marks when necessary.

(b) It must be distinctly understood that these special signals serve only to indicate the nature of the work upon which the vessel is engaged and in no way give the surveying vessel the right-of-way over other vessels or obviate the necessity for a strict observance of the rules for preventing collisions of vessels.

(c) By night a surveying vessel of the Coast and Geodetic Survey, under way and employed in hydrographic surveying, shall carry the regular lights prescribed by the rules of the road.

(d) A vessel of the Coast and Geodetic Survey, when at anchor in a fairway on surveying operations, shall display from the mast during the daytime two black balls in a vertical line and 6 feet apart. At night two red lights shall be displayed in the same manner. In the case of a small vessel the distance between the balls and between the lights may be reduced to 3 feet if necessary.

(e) Such vessels, when at anchor in a fairway on surveying operations, shall have at hand and show, if necessary, in order to attract attention, a flare-up light in addition to the lights which are, by this section, required to be carried.

80.33a Warning signals for Coast Guard vessels while handling or servicing aids to navigation.—(a) Coast Guard vessels while engaged in handling or servicing an aid to navigation during the daytime may display from the yard two orange and white vertically striped balls in a vertical line not less than three feet nor more than six feet apart, and during the nighttime may display, in a position where they may best be seen, two red lights in a vertical line not less than three feet nor more than six feet apart.

(b) Vessels, with or without tows, passing Coast Guard vessels displaying this signal, shall reduce their speed sufficiently to insure the safety of both vessels, and when passing within 200 feet of the Coast Guard vessel displaying this signal, their speed shall not exceed 5 miles per hour.

80.38 Warning signal displayed while transferring dangerous cargoes.—(a) *At a dock*. While fast to a dock, a vessel during the loading or unloading of hazardous or dangerous cargoes, such as explosives, combustible or inflammable liquids or gases, or certain chemicals in bulk, is required to display a red flag by day or a red light by night.

(b) *At anchor*. When at anchor, a vessel during the loading or unloading of such hazardous or dangerous cargoes is required to display a red flag by day. (No special warning signal is displayed at night.)

NOTE: The regulations in 46 CFR 35.30–1(a), 98.05–50(i), 98.10–45(g), 98.15–45(h), 98.20–70(g), 98.25–90(g), and 146.29–25(o) require vessels to display warning signals when loading or unloading bulk cargoes of inflammable or combustible liquids or gases, elemental phosphorus in water, sulfuric acid, hydrochloric acid, liquid chlorine, or anhydrous ammonia, or military explosives.

COMMENT: Notice particularly the difference under both Rules in the meaning of two red lights displayed in a vertical line. In the International Rules such a display calls attention to "A vessel which is not under command." Hence, a vessel which has suffered an accident affecting her maneuvering ability, one which has little or no steam pressure, a sailing vessel becalmed or in irons, all should show two red lights at night.

The Inland Rules do not provide special (two red) lights for vessels not under command. They must show the proper lights for vessels under way or at anchor.

Hence, commanding officers of naval vessels should realize that, if they show

two red lights when broken down in Inland Waters, they may be held liable if a collision with a merchant ship occurs.

Two red lights in Inland Waters (Pilot Rules) indicates a vessel alongside a wreck (80.19), stationary dredges (80.20), self-propelled or pushed dredge (80.21), pipe lines attached to dredges (80.23), hydrographic survey vessel at work (80.33), Coast Guard vessel servicing aids to navigation (80.33a).

Under the International Rules, vessels and seaplanes, not under command, carry side lights when making way through the water. When not making way, they do not carry them.

A recent case was a carrier that rammed a destroyer and suffered serious damage to her (the carrier's) bow. She was forced to proceed stern first until the forward bulkheads were shored.

INTERNATIONAL RULES

Rule 5 (Figs. 17.7 to 17.12)

(a) A sailing vessel under way and any vessel or seaplane being towed shall carry the same lights as are prescribed in Rule 2 for a power-driven vessel or a seaplane under way, respectively, with the exception of the white lights precribed therein, which they shall never carry. They shall also carry stern lights as prescribed in Rule 10, provided that vessels towed, except the last vessel of a tow, may carry, in lieu of such stern light, a small white light as prescribed in Rule 3(b).

(b) In addition to the lights prescribed in section (a), a sailing vessel may carry on the top of the foremast two lights in a vertical line one over the other, sufficiently separated so as to be clearly distinguished. The upper light shall be red and the lower light shall be green. Both lights shall be constructed and fixed as prescribed in Rule 2(a) (i) and shall be visible at a distance of at least 2 miles.

(c) A vessel being pushed ahead shall carry, at the forward end, on the starboard side a green light and on the port side a red light, which shall have the same characteristics as the lights prescribed in Rule 2(a) (iv) and (v) and shall be screened as provided in Rule 2(a) (vi), pro-

INLAND RULES

ART. 5. *A sailing vessel under way and any vessel being towed, except barges, canal boats, scows, and other vessels of nondescript type, when in tow of steam vessels, shall carry the same lights as are prescribed by article 2 for a steam vessel under way, with the exception of the white lights mentioned therein, which they shall never carry.*

ART. 10. (*a*) *A vessel when under way, if not otherwise required by these rules to carry one or more lights visible from aft, shall carry at her stern a white light, so constructed that it shall show an unbroken light over an arc of the horizon of twelve points of the compass, so fixed as to show the light six points from right aft on each side of the vessel, and of such character as to be visible at a distance of at least two miles. Such light shall be carried as nearly as practicable on the same level as the side lights.*

SEC. 2. (*a*) *The Secretary of the Department in which the Coast Guard is operating (i.e., Commandant of) shall establish such rules to be observed, on the waters described in section 1 of this Act . . . as to lights and day signals to be carried on such waters . . . by vessels and craft of all types when in tow of*

INTERNATIONAL RULES

vided that any number of vessels pushed ahead in a group shall be lighted as one vessel.

(d) Between sunrise and sunset a vessel being towed, if the length of the tow exceeds 600 feet, shall carry where it can best be seen a black diamond shape at least 2 feet in diameter.

INLAND RULES

steam vessels . . . not inconsistent with the provisions of this Act, as he from time to time may deem necessary for safety. . . .

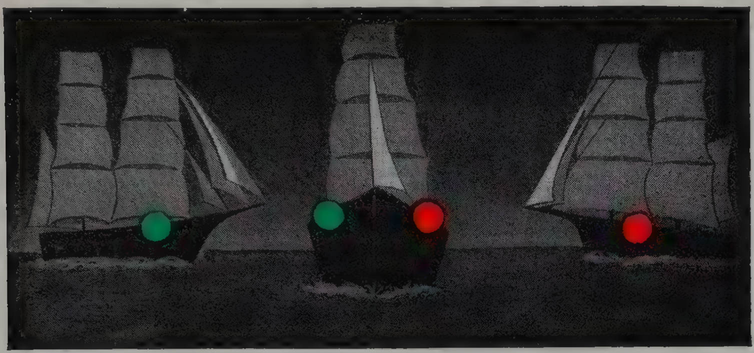


FIG. 17.7 A SAILING VESSEL. In addition stern light not visible in these sketches shall be carried in both Inland and International Waters. In latter waters, vessel may also show a red light over a green light from the top of the foremast.

PILOT RULES

80.16 Lights for barges, canalboats, scows and other nondescript vessels on certain inland waters on the Atlantic and Pacific Coasts.—(a) On the harbors, rivers, and other inland waters of the United States except the Great Lakes and their connecting and tributary waters as far east as Montreal, the Red River of the North, the Mississippi River and its tributaries above the Huey P. Long Bridge, and that part of the Atchafalaya River above its junction with the Plaquemine-Morgan City alternate waterway, and the waters described in §§ 80.16a and 80.17, barges, canalboats, scows, and other vessels of nondescript type not otherwise provided for, when being towed by steam vessels, shall carry lights as set forth in this section.

(b) Barges and canalboats towing astern of steam vessels, when towing singly, or what is known as tandem towing, shall each carry a green light on the starboard side and a red light on the port side, and a white light on the stern, except that the last vessel of such tow shall carry two lights on her stern, athwartship, horizontal to each other, not less than 5 feet apart, and not less than 4 feet above the deck house, and so placed as to show all around the horizon. A tow of one such vessel shall be lighted as the last vessel of a tow.

(c) When two or more boats are abreast, the colored lights shall be carried at the outer sides of the bows of the outside boats. Each of the outside boats in last tier of a hawser tow shall carry a white light on her stern.

(d) The white light required to be carried on stern of a barge or canalboat carrying red and green side lights except the last vessel in a tow shall be carried in a lantern so constructed that it shall show an unbroken light over an arc of the horizon of 12 points of the compass, namely, for 6 points from right aft on each side of the vessel, and shall be of such a character as to be visible on a dark night with a clear atmosphere at a distance of at least 2 miles.

(e) Barges, canalboats or scows towing alongside a steam vessel shall, if the deck, deck houses, or cargo of the barge, canalboat or scow be so high above water as to obscure the side lights of the towing steamer when being towed on the starboard side of the steamer, carry a green light upon the starboard side; and when towed on the port side of the steamer, a red light on the port side of the barge, canalboat, or scow; and if there is more than one barge, canalboat or scow abreast, the colored lights shall be displayed from the outer side of the outside barges, canalboats or scows.

(f) Barges, canalboats or scows shall, when being propelled by pushing ahead of a steam vessel, display a red light on the port bow and a green light on the starboard bow of the head barge, canalboat or scow, carried at a height sufficiently above the superstructure of the barge, canalboat or scow as to permit said side lights to be visible; and if there is more than one barge, canalboat or scow abreast, the colored lights shall be displayed from the outer side of the outside barges, canalboats or scows.

(g) The colored side lights referred to in this section shall be fitted with inboard screens so as to prevent them from being seen across the bow, and of such a character as to be visible on a dark night, with a clear atmosphere, at a distance of at least 2 miles, and so constructed as to show a uniform and unbroken light over an arc of the horizon of 10 points of the compass, and so fixed as to throw the light from right ahead to 2 points abaft the beam on either side. The minimum size of glass globes shall not be less than 6 inches in diameter and 5 inches high in the clear.

(h) Scows not otherwise provided for in this section on waters described in paragraph (a) of this section shall carry a white light at each end of each scow, except that when such scows are massed in tiers, two or more abreast, each of the outside scows shall carry a white light on its outer bow, and the outside scows in the last tier shall each carry, in addition, a white light on the outer part of the stern. The white light shall be carried not less than 8 feet above the surface of the water, and shall be so placed as to show an unbroken light all around the horizon, and shall be of such a character as to be visible on a dark night with a clear atmosphere at a distance of at least 5 miles.

(i) Other vessels of nondescript type not otherwise provided for in this sec-

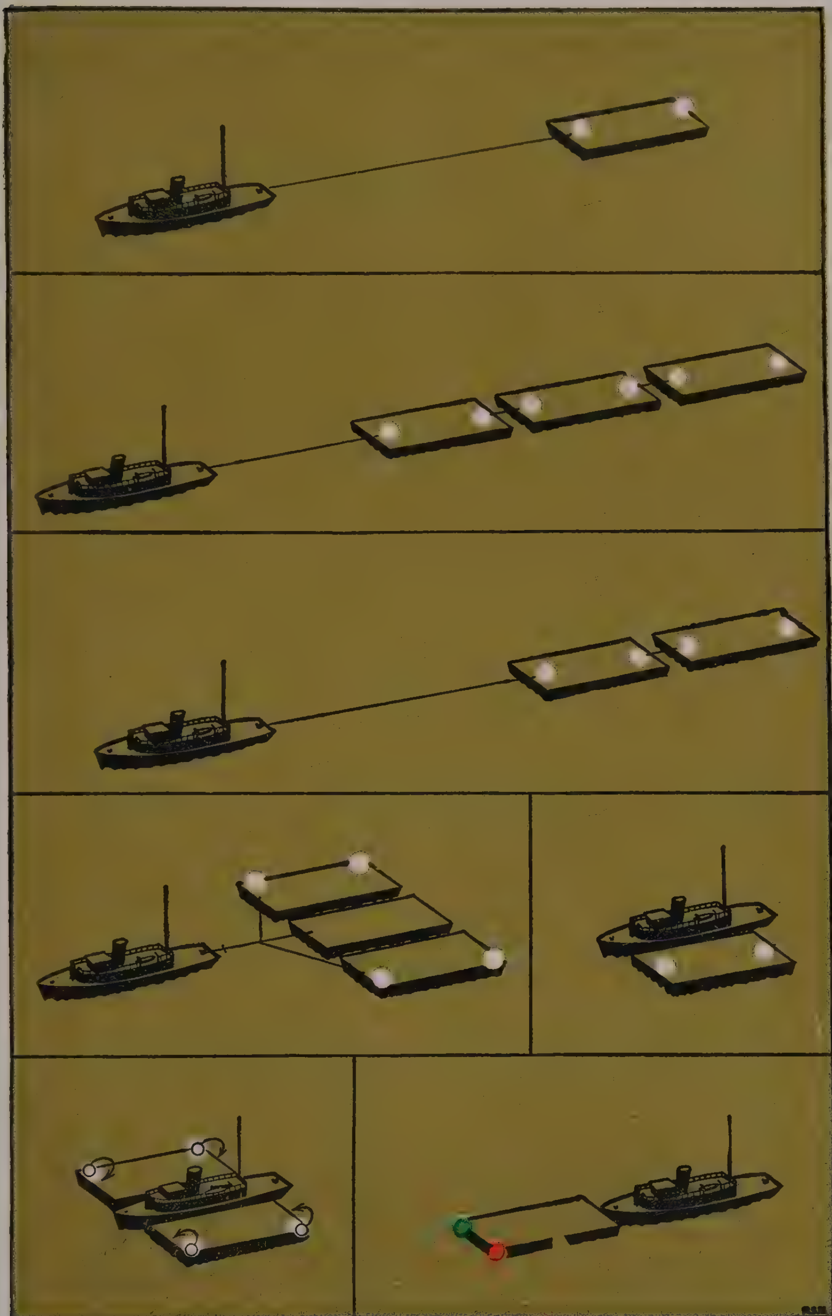


FIG. 17.8 INLAND WATER LIGHTS ON TOWED SCOWS (Hudson River area, Gulf Coast, and Gulf Intracoastal Waterway excepted)

tion shall exhibit the same lights that are required to be exhibited by scows by this section.

NOTE: The regulations in §§ 80.16 to 80.17, inclusive, are not applicable to rafts. The requirements regarding lights for rafts are in § 80.32.

80.16a Lights for barges, canalboats, scows and other nondescript vessels on certain inland waters on the Gulf Coast and the Gulf Intracoastal Waterway.—(a) On the Gulf Intracoastal Waterway and on other inland waters connected therewith or with the Gulf of Mexico from the Rio Grande, Texas, to Cape Sable (East Cape), Florida, barges, canalboats, scows, and other vessels of nondescript type not otherwise provided for, when being towed by steam vessels shall carry lights as set forth in this section.

(b) When one or more barges, canalboats, scows, or other vessels of nondescript type not otherwise provided for, are being towed by pushing ahead of a steam vessel, such tow shall be lighted by an amber light at the extreme forward end of the tow, so placed as to be as nearly as practicable on the centerline of the tow, a green light on the starboard side of the tow, so placed as to mark the maximum projection of the tow to starboard, and a red light on the port side of the tow, so placed as to mark the maximum projection of the tow to port.

(c) When one or more barges, canalboats, scows, or other vessels of nondescript type not otherwise provided for, are being towed alongside a steam vessel, there shall be displayed a white light at each outboard corner of the tow. If the deck, deckhouse, or cargo of such barge, etc., obscures the side light of the towing vessel, such barge, etc., shall also carry a green light upon the starboard side when being towed on the starboard side of a steam vessel or shall carry a red light on the port side of the barge, etc., when being towed on the port side of the steam vessel. If there is more than one such barge, etc., being towed abreast, the appropriate colored side light shall be displayed from the outer side of the outside barge.

(d) When one barge, canalboat, scow or other vessel of nondescript type not otherwise provided for, is being towed singly behind a steam vessel, such vessel shall carry four white lights, one on each corner or outermost projection of the bow and one on each corner or outermost projection of the stern.

(e) When two or more barges, canalboats, scows, or other vessels of nondescript type not otherwise provided for, are being towed behind a steam vessel in tandem, with a hawser length, between vessels, of 75 feet or more, such vessels shall carry white lights as follows:

(1) The first vessel in the tow shall carry three white lights, one on each corner or outermost projection of the bow and a white light at the stern amidships.

(2) Each intermediate vessel shall carry two white lights, one at each end amidships.

(3) The last vessel in the tow shall carry three white lights, one on each

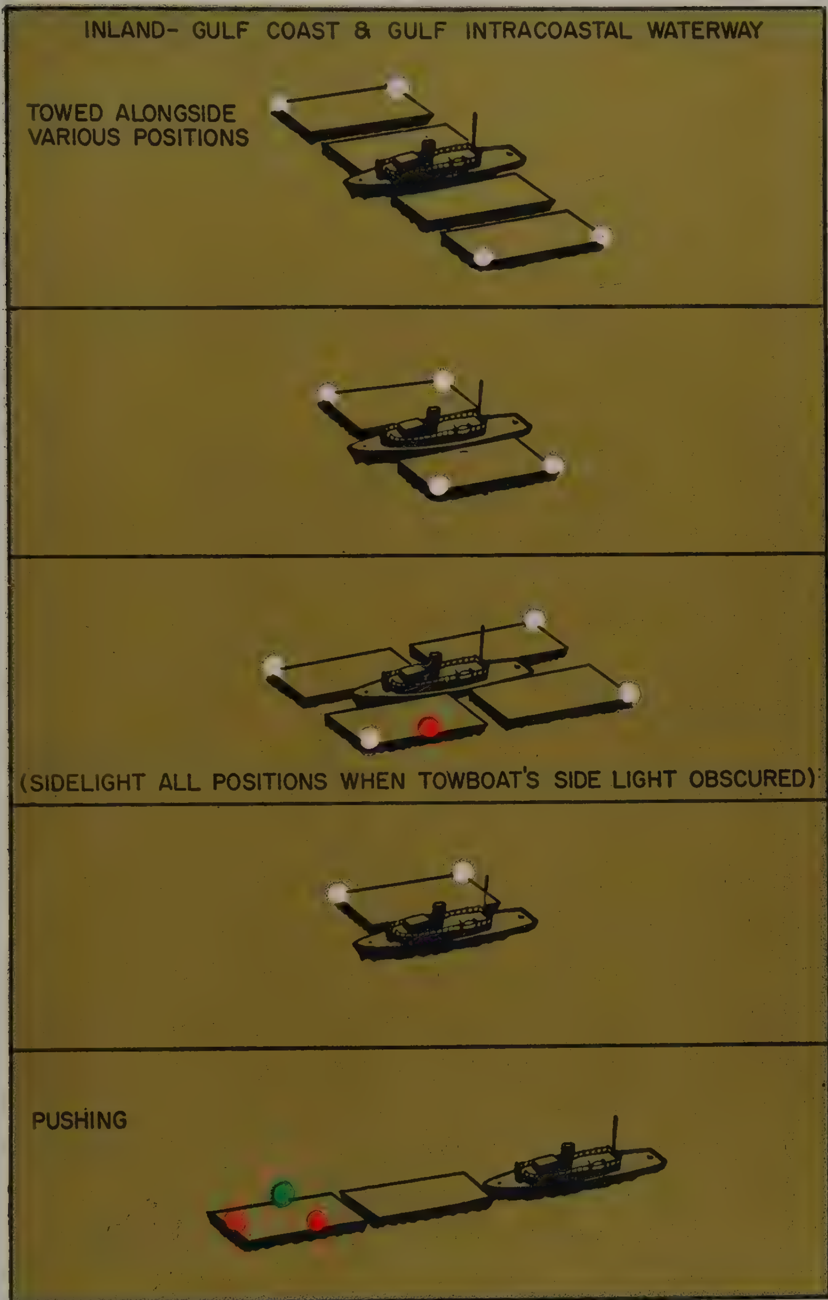


FIG. 17.9 LIGHTS ON NONDESCRIPT TOWED VESSELS

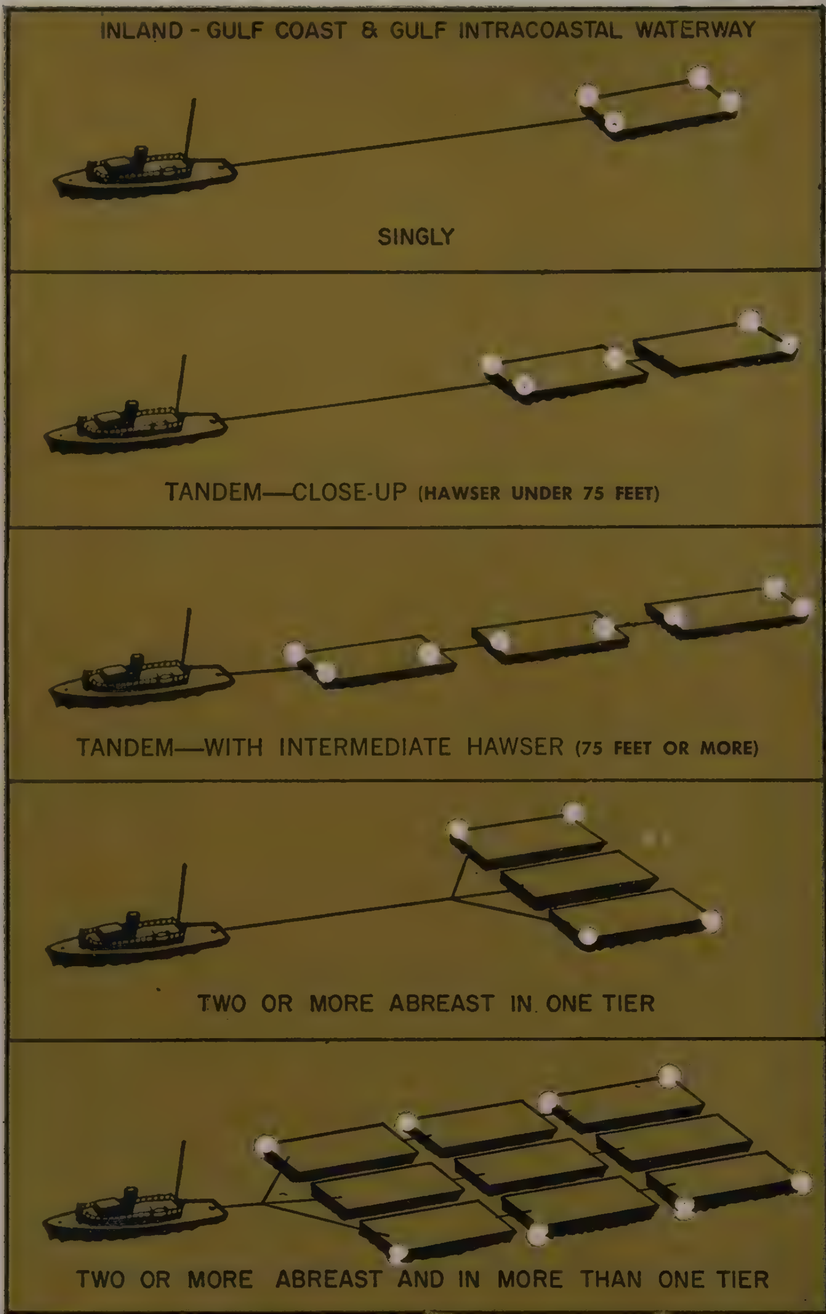


FIG. 17.10 LIGHTS ON NONDESCRIPT TOWED VESSELS

corner or outermost projection of the stern and a white light at the bow amidships.

(f) When two or more barges, canalboats, scows, or other vessels of nondescript type not otherwise provided for, are being towed behind a steam vessel in tandem, with a hawser length, between vessels, of less than 75 feet, such vessels shall carry white lights as follows:

(1) The first vessel in the tow shall carry three white lights, one on each corner or outermost projection of the bow and a white light at the stern amidships.

(2) Each intermediate vessel shall carry a white light at the stern amidships.

(3) The last vessel in the tow shall carry two white lights, one on each corner or outermost projection of the stern.

(g) When two or more barges, canalboats, scows, or other vessels of nondescript type not otherwise provided for, are being towed behind a steam vessel two or more abreast, in one or more tiers, each of the outside vessels in each tier shall carry a white light on the outboard corner of the bow, and each of the outside vessels in the last tier shall carry, in addition, a white light on the outboard corner of the stern.

(h) When one or more barges, canalboats, scows, or other vessels of nondescript type not otherwise provided for, are moored to the bank or dock in or near a fairway, such tow shall carry two white lights not less than 4 feet above the surface of the water, as follows:

(1) On a single moored barge, canalboat, scow, or other vessel of nondescript type not otherwise provided for, a light at each outboard or channelward corner.

(2) On barges, canalboats, scows, or other vessels of nondescript type not otherwise provided for, when moored in a group formation, a light on the upstream outboard or channelward corner of the outer upstream boat and a light on the downstream outboard or channelward corner of the outer downstream boat; and in addition, any boat projecting toward or into the channel from such group formation shall have two white lights similarly placed on its outboard or channelward corners.

(i) The colored side lights shall be so constructed as to show a uniform and unbroken light over an arc of the horizon of 10 points of the compass, so fixed as to show the light from right ahead to 2 points abaft the beam on their respective sides, and of such a character as to be visible at a distance of at least 2 miles, and shall be fitted with inboard screens so as to prevent either light from being seen more than half a point across the centerline of the tow.

(j) The amber light shall be so constructed as to show a uniform and unbroken light over an arc of the horizon of 20 points of the compass, so fixed as to show the light 10 points on each side of the tow, namely, from right ahead to 2 points abaft the beam on either side, and of such a character as to be visible at a distance of at least 2 miles.

(k) The white lights shall be so constructed and so fixed as to show a clear,

uniform, and unbroken light all around the horizon, and of such a character as to be visible at a distance of at least 2 miles.

(l) All the lights shall be carried at approximately the same height above the surface of the water and, except as provided in paragraph (h) of this section, shall be so placed with respect thereto as to be clear of and above all obstructions which might tend to interfere with the prescribed arc or distance of visibility.

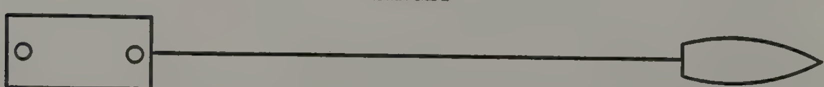
80.16b Lights for barges, canalboats, scows, and other nondescript vessels temporarily operating on waters requiring different lights.—Nothing in §§ 80.16, 80.16a, or 80.17 shall be construed as compelling barges, canalboats, scows, or other vessels of nondescript type not otherwise provided for, being towed by steam vessels, when passing through any waters coming within the scope of any regulations where lights for such boats are different from those of the waters whereon such boats are usually employed, to change their lights from those required on the waters on which their trip begins or terminates; but should such boats engage in local employment on waters requiring different lights from those where they are customarily employed, they shall comply with the local rules where employed.

80.17 Lights for barges and canalboats in tow of steam vessels on the Hudson River and adjacent waters and Lake Champlain.—(a) All nondescript vessels known as scows, car floats, lighters, and vessels of similar type, navigating the waters referred to in this section, shall carry the lights required to be carried by barges and canalboats in tow of steam vessels, as prescribed in this section.

(b) Barges and canalboats, when being towed by steam vessels on the waters of the Hudson River and its tributaries from Troy to the boundary lines of New York Harbor off Sandy Hook, as defined pursuant to section 2 of the act of Congress of February 19, 1895 (28 Stat. 672; 33 U.S.C. 151), the East River and Long Island Sound (and the waters entering thereon, and to the Atlantic Ocean), to and including Narragansett Bay, R.I., and tributaries, and Lake Champlain, shall carry lights as follows:

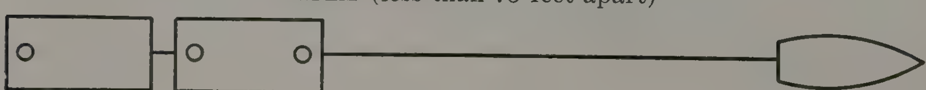
(1) Barges and canalboats being towed astern of steam vessels when towing singly shall carry a white light on the bow and a white light on the stern.

SINGLY



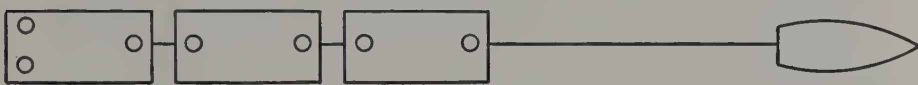
(2) When towing in tandem, "with a hawser length, between vessels, of less than 75 feet," each boat shall carry a white light on its stern and the first or hawser boat shall, in addition, carry a white light on its bow.

TANDEM (less than 75 feet apart)



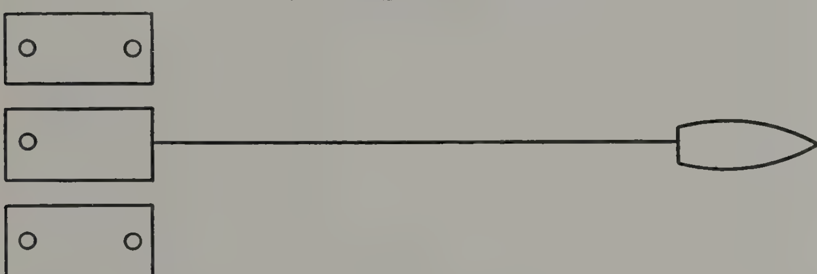
(3) When towing in tandem with a hawser length of 75 feet or more between the various boats in the tow, each boat shall carry a white light on the bow and a white light on the stern, except that the last vessel in the tow shall carry two white lights on her stern, athwartship, horizontal to each other, not less than 5 feet apart and not less than 4 feet above the deck house, and so placed as to show all around the horizon: *Provided*, That seagoing barges shall not be required to make any change in their seagoing lights (red and green) on waters coming within the scope of this section, except that the last vessel of the tow shall carry two white lights on her stern, athwartship, horizontal to each other, not less than 5 feet apart, and not less than 4 feet above the deck house, and so placed as to show all around the horizon.

TANDEM (75 feet or more apart)



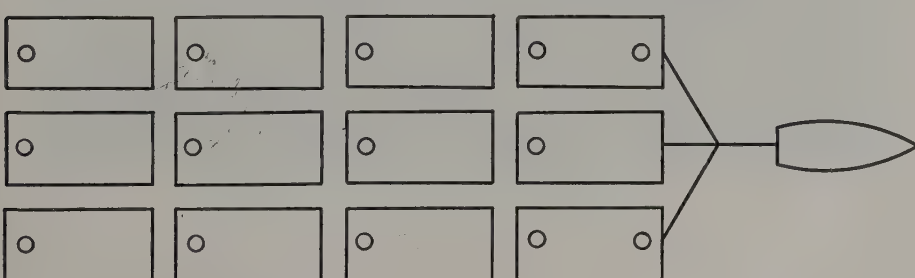
(4) Barges and canalboats when towed at a hawser, two or more abreast, when in one tier, shall each carry a white light on the stern and a white light on the bow of each of the outside boats.

TWO OR MORE ABREAST IN ONE TIER



(5) When in more than one tier, each boat shall carry a white light on its stern and the outside boats in the hawser or head tier shall each carry, in addition, a white light on the bow.

TWO OR MORE ABREAST AND IN MORE THAN ONE TIER



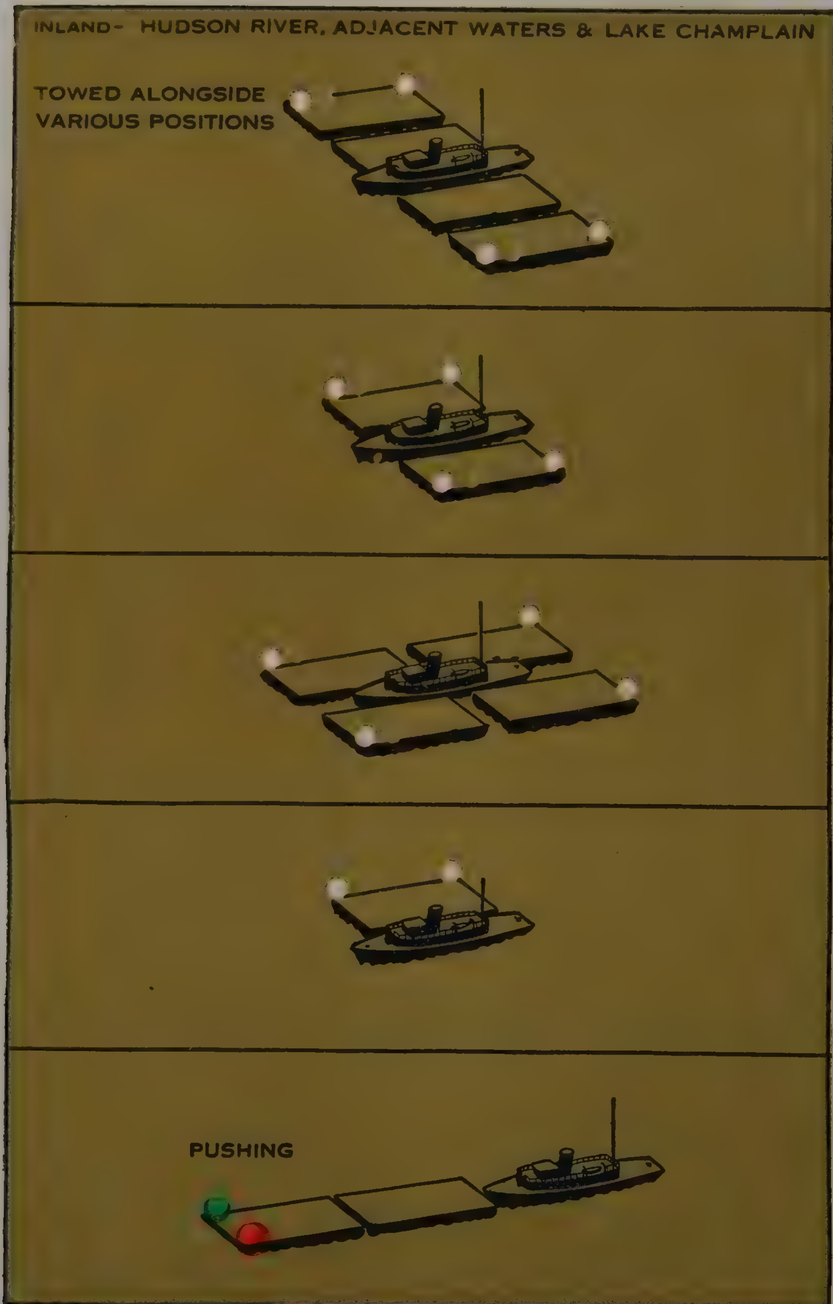


FIG. 17.11 LIGHTS ON NONDESCRIPT TOWED VESSELS

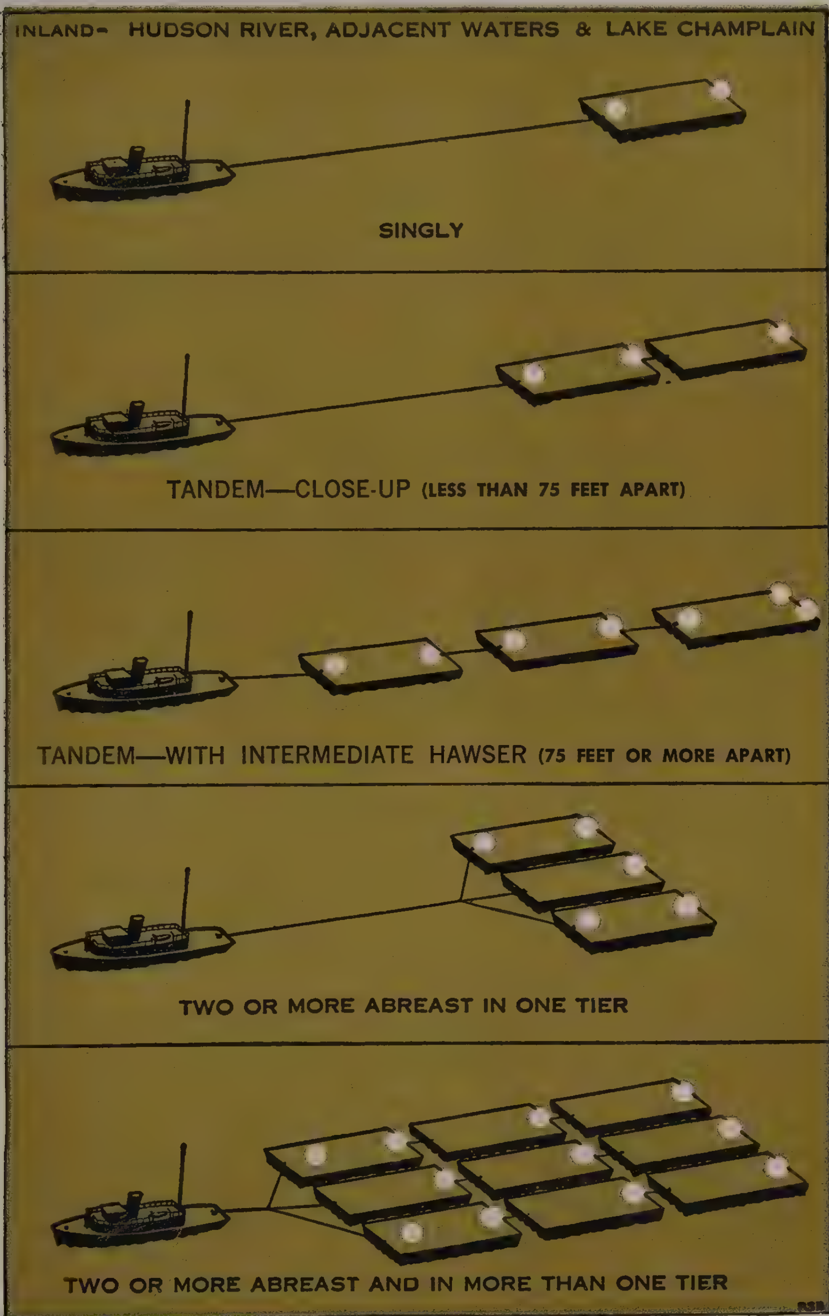
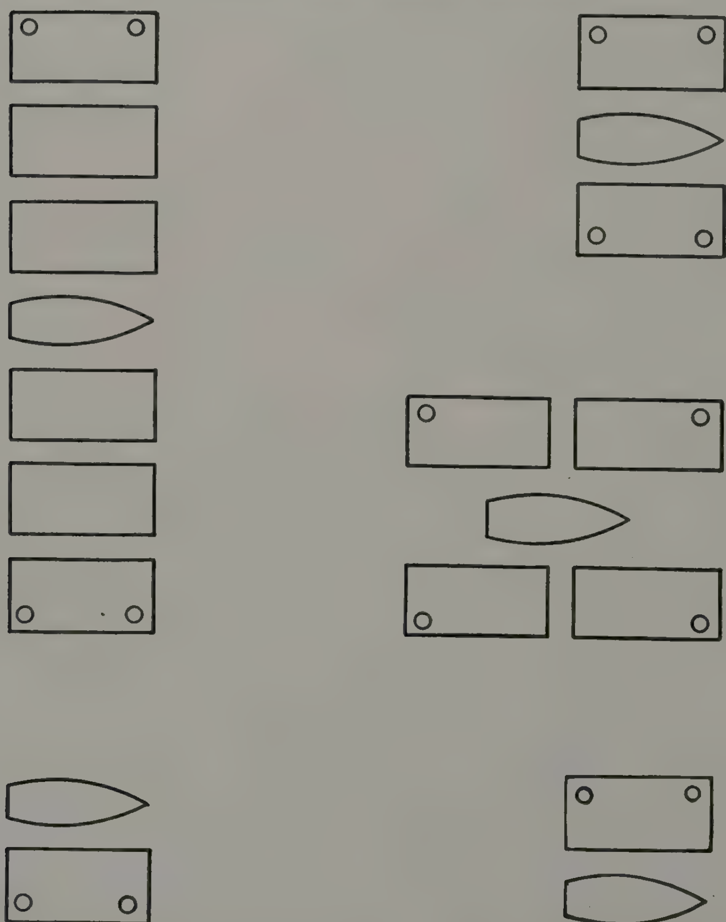


FIG. 17.12 LIGHTS ON NONDESCRIPT TOWED VESSELS

(6) The white bow lights for barges and canalboats referred to in the preceding rules shall be carried at least 10 feet and not more than 30 feet abaft the stem or extreme forward end of the vessel. On barges and canalboats required to carry a white bow light, the white light on bow and the white light on stern shall each be so placed above the hull or deck house as to show an unbroken light all around the horizon, and of such a character as to be visible on a dark night with a clear atmosphere at a distance of at least 2 miles.

(7) When nondescript vessels known as scows, car floats, lighters, barges or canalboats, and vessels of similar type, are towed alongside a steam vessel, there shall be displayed a white light at the outboard corners of the tow.

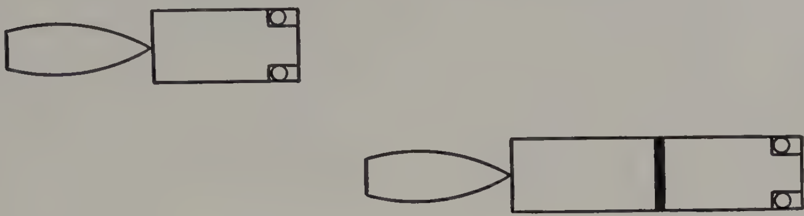
TOWED ALONGSIDE—VARIOUS POSITIONS



(8) When under way between the hours of sunset and sunrise there shall be displayed a red light on the port bow and a green light on the starboard bow of

the head barge or barges, properly screened and so arranged that they may be visible through an arc of the horizon of 10 points of the compass; that is, from right ahead to 2 points abaft the beam on either side and visible on a dark night with a clear atmosphere at a distance of at least 2 miles, and be carried at a height sufficiently above the superstructure of the barge or barges pushed ahead as to permit said side lights to be visible.

PROPULSION OF BARGE OR BARGES BY PUSHING



(9) Dump scows utilized for transportation and disposal of garbage, street sweepings, ashes, excavated material, dredging, etc., when navigating on the Hudson River or East River or the Waters tributary thereto between loading points on these waters and the dumping grounds established by competent authority outside the line dividing the high seas from the inland waters of New York Harbor, shall, when towing in tandem, carry, instead of the white lights previously required, red and green side lights on the respective and appropriate sides of the scow in addition to the white light required to be shown by an overtaken vessel.

(10) The red and green lights prescribed in this section shall be carried at a height at which they can readily be seen, the lights properly screened and so arranged as to show through an arc of the horizon of 10 points of the compass, that is, from right ahead to 2 points abaft the beam on either side and visible on a dark night with a clear atmosphere a distance of at least 2 miles.

Provided, That nothing in the rules of this section shall be construed as compelling barges or canalboats in tow of steam vessels, passing through any waters coming within the scope of said rules where lights for barges or canalboats are different from those of the waters whereon such vessels are usually employed, to change their lights from those required on the waters from which their trip begins or terminates; but should such vessels engage in local employment on waters requiring different lights from those where they are customarily employed, they shall comply with the local rules where employed.

84.05 Tows of seagoing barges within inland waters.—(a) The tows of seagoing barges when navigating the inland waters of the United States shall be limited in length to five vessels, including the towing vessel or vessels.

84.10 Hawser lengths for all tows on inland waters.—(a) The length of hawsers, between vessels, shall be limited to no more than 450 feet (75 fathoms). This length shall be the distance measured from the stern of one

vessel to the bow of the following vessel. The distance between two vessels should in all cases be as much shorter as the weather or sea will permit: *Provided,* That where, in the opinion of the master of the towing vessel, it is dangerous or inadvisable, whether on account of the state of weather or sea or otherwise, to shorten the distance between vessels, the hawsers need not be shortened to the prescribed length when entering from sea.

(b) In any event the hawsers between vessels must be shortened to the prescribed length of not more than 450 feet (75 fathoms) when the tows with inland or seagoing barges are operating in the following named localities:

(1) The James River and Hampton Roads westward of Thimble Shoal Light.

(2) The Chesapeake Bay north of the Chesapeake Bay Bridge.

(3) New York Harbor north of West Bank Light and west of Fort Schuyler.

(4) Delaware Bay north of Elbow of Cross Ledge Light.

(5) Narragansett Bay north of Brenton Reef Light.

(6) Puget Sound south of West Point.

84.20 Bunching of tows.—(a) In all cases where tows can be bunched, it should be done.

(b) Tows navigating in the North and East Rivers of New York must be bunched above a line drawn between Robbins Reef Lighthouse and Owls Head, Brooklyn, but the quarantine anchorage and the north entrance to Ambrose Channel shall be avoided in the process of bunching tows.

(c) Tows must be bunched above the mouth of the Schuylkill River, Pa.

Comment: The International Rules require side lights and a stern or steering light for "any vessel or seaplane being towed." The Inland Rules require side lights and a stern light "for any vessel towed." The Inland Rules do not cover seaplanes and the Rules except barges, canalboats, scows, and other vessels of nondescript type.

Hence, a steam- or power-driven vessel, being towed, should exhibit side lights and a stern or steering light, as appropriate, in both waters.

The Pilot Rules require two different kinds of lights for barges, canalboats, and scows, depending on the area in which they are being towed. Side lights are required in certain Inland waters, but in others only white bow and stern lights.

Such vessels are not required to change their type of lights when proceeding through an area where the other type is used unless they engage in local employment.

At present the Pilot Rules provide three separate systems of lights for barges, canalboats, scows, and other nondescript vessels—i.e., Inland Waters in general; Hudson River, adjacent waters, and Lake Champlain; Gulf Coast and Gulf Intracoastal Waterway. Those applicable to the Gulf Coast and Gulf Intracoastal Waterway were extensively revised August 9, 1958, and made effective January 1, 1959.

Other recent changes to Pilot Rules have resulted in tows in tandem, close-up, being redefined as those less than 75 feet apart, and tows in tandem, with intermediate hawser, as those 75 feet or more apart.

The Commandant of the Coast Guard (Exec. Order 9083, etc.) is charged with the power to make special rules to govern the lights to be carried by ferryboats, by barges, canalboats, etc., in tow of steam vessels, by dredges and vessels working on wrecks, and other nondescript vessels not provided for in the statutory rules.

The Act of August 8, 1917 (40 Stat. L 250) gives the Secretary of the Army the right to issue regulations for the use, administration, and navigation of navigable waters of the United States, "covering all matters not specifically designated by law to some other executive department." Regulations issued under the Act are usually published as Corps of Engineers regulations.

INTERNATIONAL RULES

Rule 6

(a) When it is not possible on account of bad weather or other sufficient cause to fix the green and red sidelights, these lights shall be kept at hand lighted and ready for immediate use, and shall, on the approach of or to other vessels, be exhibited on their respective sides in sufficient time to prevent collision, in such manner as to make them most visible, and so that the green light shall not be seen on the port side nor the red light on the starboard side, nor, if practicable, more than 22½ degrees (2 points) abaft the beam on their respective sides.

(b) To make the use of these portable lights more certain and easy, the lanterns containing them shall each be painted outside with the colour of the lights they respectively contain, and shall be provided with proper screens.

INLAND RULES

ART. 6. *Whenever, as in the case of vessels of less than ten gross tons under way during bad weather, the green and red side lights cannot be fixed, these lights shall be kept at hand, lighted and ready for use; and shall, on the approach of or to other vessels, be exhibited on their respective sides in sufficient time to prevent collision, in such manner as to make them most visible, and so that the green light shall not be seen on the port side nor the red light on the starboard side, nor, if practicable, more than two points abaft the beam on their respective sides. To make the use of these portable lights more certain and easy the lanterns containing them shall each be painted outside with the color of the light they respectively contain, and shall be provided with proper screens.*

COMMENT: The International Rule applies to all vessels. The dividing line in Inland Waters is 10 gross tons.

18

Lights and Shapes of Identification, Specific Rules (Articles) 7–14

INTERNATIONAL RULES

Rule 7 (Fig. 18.1)

Power-driven vessels of less than 65 feet in length, vessels under oars or sails of less than 40 feet in length, and rowing boats, when under way shall not be required to carry the lights prescribed in Rules 2, 3 and 5, but if they do not carry them they shall be provided with the following lights:—

(a) Power-driven vessels of less than 65 feet in length, except as provided in sections (b) and (c), shall carry:—

(i) In the forepart of the vessel, where it can best be seen, and at a height above the gunwale of not less than 9 feet, a white light constructed and fixed as prescribed in Rule 2(a) (i) and of such a character as to be visible at a distance of at least 3 miles.

(ii) Green and red sidelights constructed and fixed as prescribed in Rule 2(a) (iv) and (v), and of such a character as to be visible at a distance of at least 1 mile, or a combined lantern showing a green light and a red light from right ahead to 22½ degrees (2 points) abaft the beam on their respective sides. Such lantern shall be carried not less than 3 feet below the white light.

(b) Power-driven vessels of less than 65 feet in length when towing or pushing another vessel shall carry:—

INLAND RULES

Article 7

Not in Inland Rules.

Not in Inland Rules.

INTERNATIONAL RULES	*INLAND RULES*
(i) In addition to the sidelights or the combined lantern prescribed in section (a) (ii) two white lights in a vertical line, one over the other not less than 4 feet apart. Each of these lights shall be of the same construction and character as the white light prescribed in section (a) (i) and one of them shall be carried in the same position. In a vessel with a single mast such lights may be carried on the mast.	
(ii) Either a stern light as prescribed in Rule 10 or in lieu of that light a small white light abaft the funnel or aftermast for the tow to steer by, but such light shall not be visible forward of the beam.	
(c) Power-driven vessels of less than 40 feet in length may carry the white light at a less height than 9 feet above the gunwale, but it shall be carried not less than 3 feet above the sidelights or the combined lantern prescribed in section (a) (ii).	*Not in Inland Rules.*
(d) Vessels of less than 40 feet in length, under oars or sails, except as provided in section (f), shall, if they do not carry the sidelights, carry, where it can best be seen, a lantern showing a green light on one side and a red light on the other, of such a character as to be visible at a distance of at least 1 mile, and so fixed that the green light shall not be seen on the port side, nor the red light on the starboard side. Where it is not possible to fix this light, it shall be kept ready for immediate use and shall be exhibited in sufficient time to prevent collision and so that the green light shall not be seen on the port side nor the red light on the starboard side.	*Not in Inland Rules.*
(e) The vessels referred to in this Rule when being towed shall carry the sidelights or the combined lantern prescribed in sections (a) or (d) of this Rule, as appropriate, and a stern light as prescribed in Rule 10, or, except the last vessel of the	*Not in Inland Rules.*

INTERNATIONAL RULES

tow, a small white light as prescribed in section (b) (ii). When being pushed ahead they shall carry at the forward end the sidelights or combined lantern prescribed in sections (a) or (d) of this Rule, as appropriate, provided that any number of vessels referred to in this Rule when pushed ahead in a group shall be lighted as one vessel under this Rule unless the overall length of the group exceeds 65 feet when the provisions of Rule 5(c) shall apply.

(f) Small rowing boats, whether under oars or sail, shall only be required to have ready at hand an electric torch or a lighted lantern showing a white light, which shall be exhibited in sufficient time to prevent collision.

(g) The vessels and boats referred to in this Rule shall not be required to carry the lights or shapes prescribed in Rules 4(a) and 11(e) and the size of their day signals may be less than is prescribed in Rules 4(c) and 11(c).

INLAND RULES

ART. 7. *Rowing boats, whether under oars or sail, shall have ready at hand a lantern showing a white light which shall be temporarily exhibited in sufficient time to prevent collision.*

ART. 9. (*d*) *Rafts, or other water craft not herein provided for, navigating by hand power, horse power, or by the current of the river, shall carry one or more good white lights, which shall be placed in such manner as shall be prescribed by the Commandant of the Coast Guard.*

PILOT RULES

80.32 Lights for rafts and other craft.—(a) Any vessel propelled by hand power, horse power, or by the current of the river, except rafts and rowboats, shall carry one white light forward not less than 8 feet above the surface of the water.

(b) Any raft while being propelled by hand power, by horse power, or by the current of the river, while being towed, or while anchored or moored in or near a channel or fairway, shall carry white lights as follows:

(1) A raft of one crib in width shall carry one white light at each end of the raft.

(2) A raft of more than one crib in width shall carry four white lights, one on each outside corner.

(3) An unstable log raft of one bag or boom in width shall carry at least two but not more than four white lights in a fore-and-aft line, one of which shall be at each end. The lights may be closely grouped clusters of not more than three white lights rather than single lights.

(4) An unstable log raft of more than one bag or boom in width shall carry

four white lights, one on each outside corner. The lights may be closely grouped clusters of not more than three white lights rather than single lights.

(c) The white lights required by this section shall be carried from sunset to sunrise, in a lantern so fixed and constructed as to show a clear, uniform, and unbroken light, visible all around the horizon, and of such intensity as to be visible on a dark night with a clear atmosphere at a distance of at least one mile. The lights for rafts shall be suspended from poles of such height that the lights shall not be less than 8 feet above the surface of the water, except that the lights prescribed for unstable log rafts shall not be less than 4 feet above the water.

ACT OF APRIL 25, 1940; EXCERPTS FROM

AN ACT TO AMEND LAWS FOR PREVENTING COLLISIONS OF VESSELS, TO REGULATE THE EQUIPMENT OF CERTAIN MOTORBOATS ON THE NAVIGABLE WATERS OF THE UNITED STATES, AND FOR OTHER PURPOSES

Motorboat defined; inspection

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the word "motorboat" where used in this Act shall include every vessel propelled by machinery and not more than sixty-five feet in length except tugboats and towboats propelled by steam. The length shall be measured from end to end over the deck, excluding sheer: *Provided,* That the engine, boiler or other operating machinery shall be subject to inspection by the Coast Guard, and to their approval of the design thereof, on all said motorboats, which are more than forty feet in length, and which are propelled by machinery driven by steam.

Classes of motorboats

SEC. 2. Motorboats subject to the provisions of this Act shall be divided into four classes as follows:

Class A. Less than sixteen feet in length.

Class 1. Sixteen feet or over and less than twenty-six feet in length.

Class 2. Twenty-six feet or over and less than forty feet in length.

Class 3. Forty feet or over and not more than sixty-five feet in length.

Lights

SEC. 3. Every motorboat in all weathers from sunset to sunrise shall carry and exhibit the following lights when under way, and during such time no other lights which may be mistaken for those prescribed shall be exhibited:

(a) Every motorboat of classes A and 1 shall carry the following lights:

First. A bright white light aft to show all around the horizon.

Second. A combined lantern in the fore part of the vessel and lower than the white light aft, showing green to starboard and red to port, so fixed as to throw

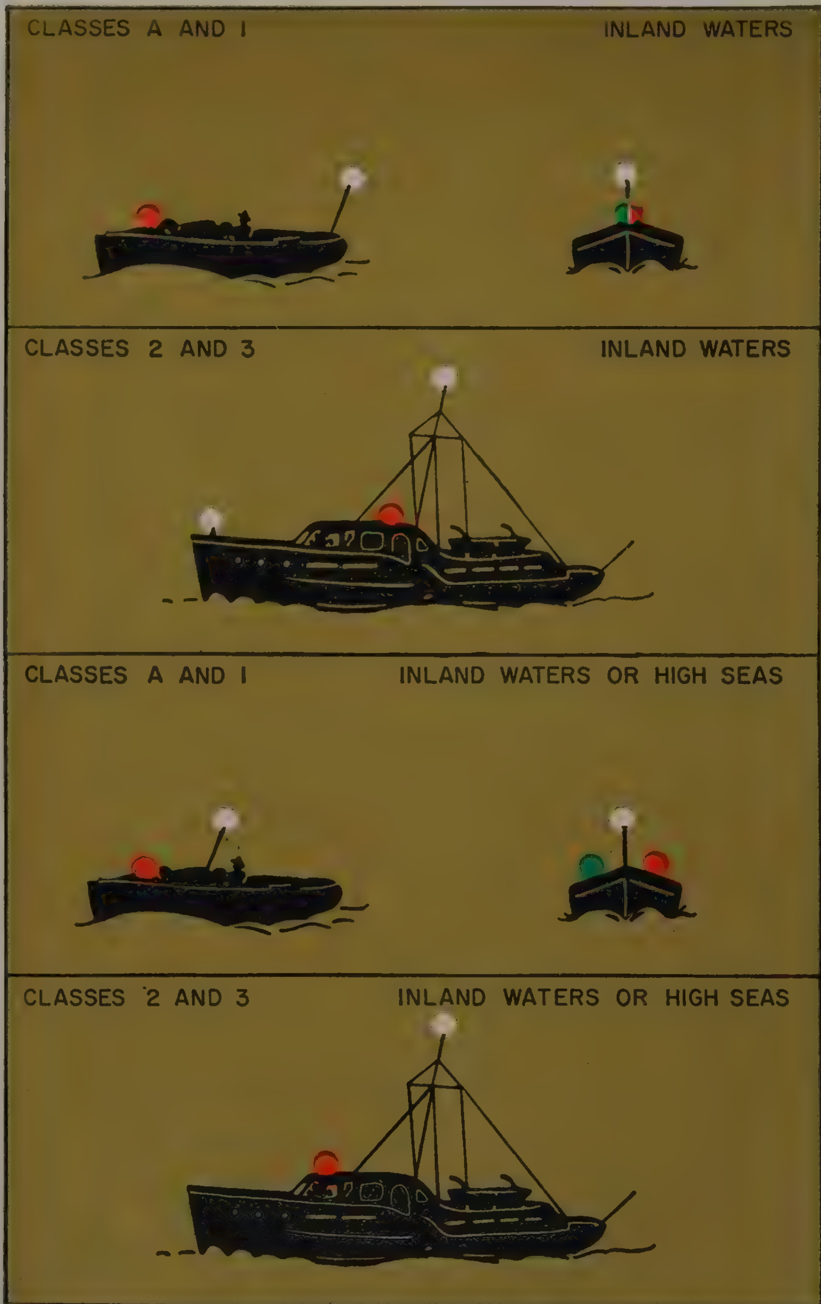


FIG. 18.1 MOTORBOATS. LIGHTS (For other combinations, see text)

the light from right ahead to two points abaft the beam on their respective sides.

(b) Every motorboat of classes 2 and 3 shall carry the following lights:

First. A bright white light in the fore part of the vessel as near the stem as practicable, so constructed as to show an unbroken light over an arc of the horizon of twenty points of the compass, so fixed as to throw the light ten points on each side of the vessel; namely, from right ahead to two points abaft the beam on either side.

Second. A bright white light aft to show all around the horizon and higher than the white light forward.

Third. On the starboard side a green light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the starboard side. On the port side a red light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the port side. The said side lights shall be fitted with inboard screens of sufficient height so set as to prevent these lights from being seen across the bow.

(c) Motorboats of classes A and 1 when propelled by sail alone shall carry the combined lantern, but not the white light aft, prescribed by this section. Motorboats of classes 2 and 3, when so propelled, shall carry the colored side lights, suitably screened, but not the white lights prescribed by this section. Motorboats of all classes, when so propelled, shall carry, ready at hand, a lantern or flashlight showing a white light which shall be exhibited in sufficient time to avert collision.

(d) Every white light prescribed by this section shall be of such character as to be visible at a distance of at least two miles. Every colored light prescribed by this section shall be of such character as to be visible at a distance of at least one mile. The word "visible" in this Act, when applied to lights, shall mean visible on a dark night with clear atmosphere.

(e) When propelled by sail and machinery any motorboat shall carry the lights required by this section for a motorboat propelled by machinery only.

(f) Any motorboat may carry and exhibit the lights required by the Regulations for preventing Collisions at Sea, 1960, Act of September 24, 1963 (77 Stat. 194–210; 33 U.S.C. 1051–1053, 1061–1094), as amended, in lieu of the lights required by this section.

NOTE: On motorboats of classes A and 1 the aft white all around light or the 12 point white stern light may be located off the centerline.

INTERPRETIVE RULINGS—INLAND RULES

86.05–1 White lights for motorboats carried on centerline.—Every white light required by section 3 of the Act of April 25, 1940, as amended (46 U.S.C. 526b), shall be carried on the centerline of the motorboat, except that the all-

around white light aft on a motorboat of Class A or 1 may be carried off the centerline.

86.05–5 Stern lights for all vessels.—Article 10 of section 1 of the Act of June 7, 1897, as amended by the Act of August 14, 1958 (33 U.S.C. 179), requires "a vessel when underway, if not otherwise required by these rules to carry one or more lights visible from aft, shall carry at her stern a white light, * * *" and this requirement shall be applied to all vessels, including but not limited to, tugs, barges, sail vessels, motorboats, when propelled by sail alone, etc.

INTERPRETIVE RULING—INTERNATIONAL RULES

85.05–1 Stern light for motorboats operating on the high seas carried on centerline.—Rule 10 of the "International Rules" (33 U.S.C. 145h) states, "A vessel when underway shall carry at her stern a white light, * * *." This 12-point white stern light shall be carried on the centerline of every motorboat of Class A, 1, 2, or 3, except that on a motorboat of Class A or 1 this light may be carried off the centerline.

COMMENT: This International Rule prescribes lights for power-driven vessels of less than 65 feet in length, vessels under oars or sail of less than 40 feet in length and rowing boats.

The Inland (Pilot) Rules prescribe lights for rowing boats, rafts, or other water craft not provided for, navigated by hand power, horsepower, or the current.

The Inland Pilot Rules supplement the Inland Rules.

The International Rule divides power-driven vessels into two classes: (a) power-driven vessels of less than 65 feet in length and (b) those of less than 40 feet in length.

From the point of view of an approaching vessel there is litle difference in the lights carried. Both carry a masthead light and side lights, separated or in a combined lantern.

Vessels under oars or sail of less than 40 feet in length carry permanent or portable side lights, separate or combined.

The Motor Boat Act of 1940 applies to every vessel in U.S. waters propelled in whole or in part by machinery and not more than 65 feet in length except tug boats and tow boats propelled by steam. The Act applies to ship's boats and to sailing auxiliaries. The Act divides motorboats into two groups as far as navigation lights are concerned: (a) under 26 feet in length and (b) 26–65 feet in length, inclusive. Group (a) carries an all-around white light aft and combined side lights forward. Group (b) carries a 20-point white light near the stem, an all-around white light, above and abaft the forward white light, and separated side lights. Note, however, that by an amendment enacted June 4, 1956, any size motorboat may carry International Rules lights in Inland Waters rather than lights specified in the Motorboat Act itself.

Sections 3(a) and (b) apply to motorboats propelled by machinery. New Section 3(c) applies to motorboats propelled by sail. New Section 3(e) applies to motorboats propelled by both sail and machinery. Both changes were enacted June 4, 1956. The effect of the new sections is to require motorboats to show lights in conformance with their propulsion.

INTERNATIONAL RULES

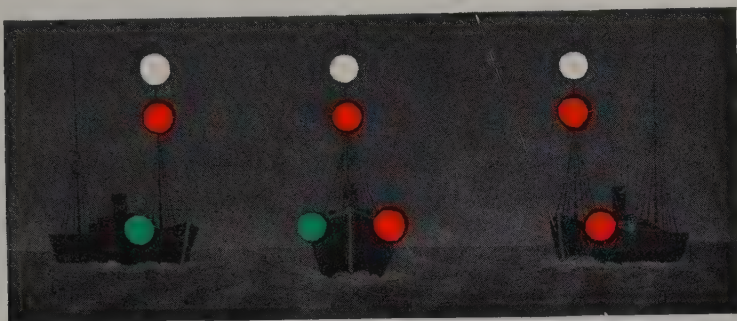
Rule 8 (Fig. 18.2)

(a) A power-driven pilot-vessel when engaged on pilotage duty and under way:—

(i) Shall carry a white light at

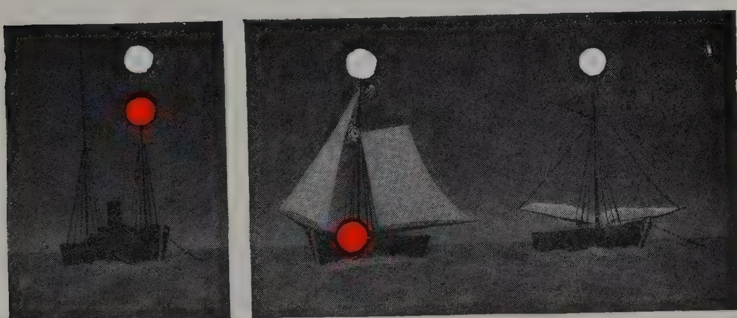
INLAND RULES

ART. 8. *Pilot vessels when engaged on their stations on pilotage duty shall not show the lights required for other vessels, but shall carry a white*



INTERNATIONAL AND INLAND

Power-Driven or Steam Pilot Vessel Under Way, Shows Flare-up or Intermittent Light



INTERNATIONAL AND INLAND

At Anchor (Shows Flare-up at Intervals) Steam Pilot Vessel

Under Way (Shows Flare-up at Intervals) (Shows Side Lights at Intervals)

At Anchor on Duty (Shows Flare-up at Intervals)

Sailing Pilot Vessel

All pilot vessels at anchor in International Waters shall also display anchor lights

FIG. 18.2

INTERNATIONAL RULES

the masthead at a height of not less than 20 feet above the hull, visible all round the horizon at a distance of at least 3 miles and at a distance of 8 feet below it a red light similar in construction and character. If such a vessel is of less than 65 feet in length she may carry the white light at a height of not less than 9 feet above the gunwale and the red light at a distance of 4 feet below the white light.

(ii) Shall carry the sidelights or lanterns prescribed in Rule 2(a) (iv) and (v) or Rule 7(a) (ii) or (d), as appropriate, and the stern light prescribed in Rule 10.

(iii) Shall show one or more flare-up lights at intervals not exceeding 10 minutes. An intermittent white light visible all round the horizon may be used in lieu of flare-up lights.

(b) A sailing pilot-vessel when engaged on pilotage duty and under way:—

(i) Shall carry a white light at the masthead visible all round the horizon at a distance of at least 3 miles.

(ii) Shall be provided with the sidelights or lantern prescribed in Rules 5(a) or 7(d), as appropriate, and shall, on the near approach of or to other vessels, have such lights ready for use, and shall show them at short intervals to indicate the direction in which she is heading, but the green light shall not be shown on the port side nor the red light on the starboard side. She shall also carry the stern light prescribed in Rule 10.

(iii) Shall show one or more flare-up lights at intervals not exeeding 10 minutes.

(c) A pilot-vessel when engaged on pilotage duty and not under way shall carry the lights and show the flares prescribed in sections (a) (i) and (iii) or (b) (i) and (iii), as appropriate, and if at anchor shall also

INLAND RULES

light at the masthead, visible all around the horizon, and shall also exhibit a flare-up light or flare-up lights at short intervals, which shall never exceed fifteen minutes.

On the near approach of or to other vessels they shall have their side lights lighted, ready for use, and shall flash or show them at short intervals, to indicate the direction in which they are heading, but the green light shall not be shown on the port side nor the red light on the starboard side.

A pilot vessel of such a class as to be obliged to go alongside of a vessel to put a pilot on board may show the white light instead of carrying it at the masthead, and may, instead of the colored lights above mentioned, have at hand, ready for use, a lantern with a green glass on the one side and a red glass on the other, to be used as prescribed above.

A steam pilot vessel, when engaged on her station on pilotage duty and in waters of the United States, and not at anchor, shall in addition to the lights required for all pilot boats, carry at a distance of eight feet below her white masthead light a red light, visible all around the horizon and of such a character as to be visible on a dark night with a clear atmosphere at a distance of at least two miles, and also the colored side lights required to be carried by vessels when under way.

When engaged on her station on pilotage duty and in waters of the United States, and at anchor, she shall carry in addition to the lights required for all pilot boats the red light above mentioned, but not the colored side lights. When not engaged on her station on pilotage duty, she shall carry the same lights as other steam vessels.

Pilot vessels, when not engaged on

INTERNATIONAL RULES

carry the anchor lights prescribed in Rule 11.

(d) A pilot-vessel when not engaged on pilotage duty shall show the lights or shapes for a similar vessel of her length.

INLAND RULES

their station on pilotage duty, shall carry lights similar to those of other vessels of their tonnage.

Not in Pilot Rules

COMMENT: The International Rules (1960) divide pilot vessels into the following classes:

1. Sailing pilot vessels.
2. Power-driven pilot vessels.

The Inland Rules divide pilot vessels as follows:

1. All pilot vessels.
2. Pilot vessels which go alongside.
3. Steam pilot vessels.

These classes under way in both waters may be grouped as follows:

1. All pilot vessels carry or show a white all-around masthead light.
2. Power-driven or steam pilot vessels carry an all-around red light below the white masthead light.
3. All pilot vessels show steady or flashing side lights underway.
4. All pilot vessels show a flare-up or intermittent white light at intervals.

Pilot vessels on station at anchor show anchor lights in International Waters, but not in Inland Waters, the white masthead light, the red light below it if the vessel is steam or power-driven, and a flare-up or flashing white light.

All pilot vessels carry the same lights as other vessels of their tonnage and class when not on station.

The differences between the two Rules are: (a) the intervals between flares, (b) distances of visibility, (c) the use of an intermittent light in place of a flare-up light on power-driven pilot vessels in International Waters, and (d) the classification of pilot vessels.

COURT DECISIONS: "When such pilot-boat is cruising (off the southern New Jersey coast), I think it clear that she is a pilot-vessel engaged on her station on pilotage duty." (THE HAVERTON, 31 F 563.)

INTERNATIONAL RULES

Rule 9 (Figs. 18.3 and 18.4)

(a) Fishing vessels when not engaged in fishing shall show the lights or shapes for similar vessels of their length.

INLAND RULES

Article 9 (Fig. 18.5)

ART. 9. (*a*) *Fishing vessels of less than ten gross tons, when under way and when not having their nets, trawls, dredges, or lines in the water,*

INTERNATIONAL RULES	*INLAND RULES*
	shall not be obliged to carry the colored side lights; but every such vessel shall, in lieu thereof, have ready at hand a lantern with a green glass on one side and a red glass on the other side, and on approaching to or being approached by another vessel such lantern shall be exhibited in sufficient time to prevent collision, so that the green light shall not be seen on the port side nor the red light on the starboard side.

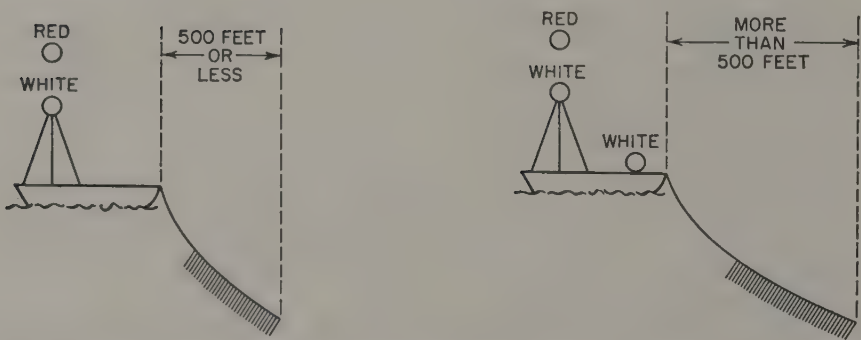


FIG. 18.3 VESSELS FISHING WITH NETS OR LINES EXCEPT TROLLING. INTERNATIONAL (Sidelights are shown when making way, also the stern light)

INTERNATIONAL RULES

(b) Vessels engaged in fishing, when under way or at anchor, shall show only the lights and shapes prescribed in this Rule, which lights and shapes shall be visible at a distance of at least 2 miles.

(c) (i) Vessels when engaged in trawling, by which is meant the dragging of a dredge net or other apparatus through the water, shall carry two lights in a vertical line, one over the other, not less than 4 feet nor more than 12 feet apart. The upper of these lights shall be green and the lower light white and each shall be visible all round the horizon The lower of these two lights shall be carried at a height above the sidelights not less than twice the distance between the two vertical lights.

INLAND RULES

(b) All fishing vessels and fishing boats of ten gross tons or upward, when under way and when not having their nets, trawls, dredges, or lines in the water, shall carry and show the same lights as other vessels under way.

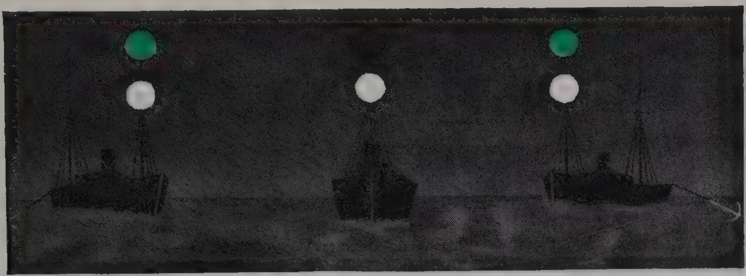
(c) All vessels, when trawling, dredging, or fishing with any kind of drag nets or lines, shall exhibit, from some part of the vessel where they can be best seen, two lights. One of these lights shall be red and the other shall be white. The red light shall be above the white light, and shall be at a vertical distance from it of not less than six feet and not more than twelve feet; and the horizontal distance between them, if any, shall not be more than ten feet. These two lights shall be of such a

INTERNATIONAL RULES

(ii) Such vessels may in addition carry a white light similar in construction to the white light prescribed in Rule 2(a) (i) but such light shall be carried lower than and abaft the all-round green and white lights.

INLAND RULES

character and contained in lanterns of such construction as to be visible all around the horizon, the white light a distance of not less than three miles and the red light of not less than two miles.

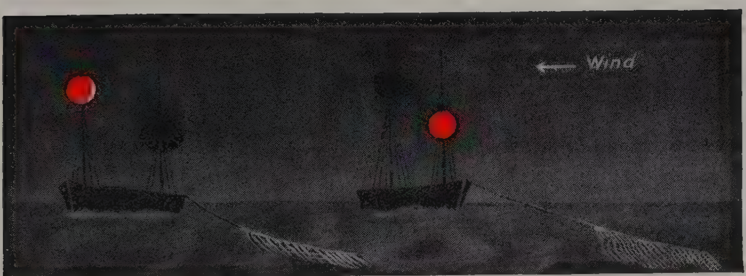


INTERNATIONAL

Power-Driven Trawler

May show white masthead light lower and aft

Sidelights and stern light shown making way



INTERNATIONAL

Line Fishing | Drift Net Fishing

Not more than 500 feet

Sidelights and stern light shown making way

FIG. 18.4 FISHING VESSELS' LIGHTS

(d) Vessels when engaged in fishing, except vessels engaged in trawling, shall carry the lights prescribed in section (c) (i) except that the upper of the two vertical lights shall be red. Such vessels if of less than 40 feet in length may carry the red light at a height of not less than 9

INTERNATIONAL RULES

feet above the gunwale and the white light not less than 3 feet below the red light.

(e) Vessels referred to in sections (c) and (d), when making way through the water, shall carry the sidelights or lanterns prescribed in Rule 2(a) (iv) and (v) or Rule 7(a) (ii) or (d), as appropriate, and the stern light prescribed in

FIG. 18.5

Rule 10. When not making way through the water they shall show neither the sidelights nor the stern light.

(f) Vessels referred to in section (d) with outlying gear extending more than 500 feet horizontally into the seaway shall carry an additional all-round white light at a horizontal distance of not less than 6 feet nor more than 20 feet away from the vertical lights in the direction of the outlying gear. This additional white light shall be placed at a height not exceeding that of the white light prescribed in section (c) (i) and not lower than the sidelights.

(g) In addition to the lights which they are required by this Rule to carry, vessels engaged in fishing may, if necessary in order to attract the attention of an approaching vessel, use a flare-up light, or may direct the beam of their searchlight

INLAND RULES

Not in Inland Rules.

Not in Inland Rules.

Not in Inland Rules.

INTERNATIONAL RULES

in the direction of a danger threaten-the approaching vessel, in such a way as not to embarrass other vessels. They may also use working lights but fishermen shall take into account that especially bright or insufficiently screened working lights may impair the visibility and distinctive character of the lights prescribed in this Rule.

(h) By day vessels when engaged in fishing shall indicate their occupation by displaying where it can best be seen a black shape consisting of two cones each not less than 2 feet in diameter with their points together one above the other. Such vessels if of less than 65 feet in length may substitute a basket for such black shape. If their outlying gear extends more than 500 feet horizontally into the seaway vessels engaged in fishing shall display in addition one black conical shape, point upwards, in the direction of the outlying gear.

NOTE: Vessels fishing with trolling lines are not "engaged in fishing" as defined in Rule 1(c)(xiv).

INLAND RULES

Not in Inland Rules.

PILOT RULES

80.32a Day marks for fishing vessels with gear out.—All vessels or boats fishing with nets or lines or trawls, when under way, shall in daytime indicate their occupation to an approaching vessel by displaying a basket where it can best be seen. If vessels or boats at anchor have their gear out, they shall, on the approach of other vessels, show the same signal in the direction from the anchor back towards the nets or gear.

COMMENT: *Inland Rules.* The Inland Rules have only one rule for fishing vessels, i.e., those which are trawling, dredging, or fishing at night with any kind of drag nets or lines. See Article 9(c). The remaining two sub-paragraphs, (a) and (b), in Article 9, prescribe lights for two sizes of fishing vessels when under way and not fishing, i.e., those of less than 10 gross tons and those of 10 gross tons or upward.

The Pilot Rules provide distinctive signals for vessels or boats fishing with nets or lines or trawls, under way and at anchor in the daytime. The Inland and Pilot Rules supplement each other.

Under International Rules, day signals are the same under way and at

anchor. A different daymark is prescribed, depending on whether the gear is within or in excess of 500 feet.

International Rules for Fishing. The International Rules divide fishing vessels into four classes:

1. Vessels fishing with trolling lines (see 1(c) xiv).
2. Vessels fishing with nets or lines, except trolling, extending from a vessel not more than 500 feet (see 9(d)).
3. The same type but extending more than 500 feet (see 9(f)).
4. Trawlers (see 9(c)).

Fishing vessels when not fishing are required to show the lights or shapes of similar vessels of their tonnage.

They are permitted to use working lights and may show a flare-up light to attract attention of approaching vessels.

The identifying lights and shapes are shown according to the type of fishing and not on the basis of being underway vice being at anchor.

INTERNATIONAL RULES

Rule 10

(a) Except where otherwise provided in these Rules, a vessel when under way shall carry at her stern a white light, so constructed that it shall show an unbroken light over an arc of the horizon of 135 degrees (12 points of the compass), so fixed as to show the light 67½ degrees (6 points) from right aft on each side of the vessel, and of such a character as to be visible at a distance of at least 2 miles.

(b) In a small vessel, if it is not possible on account of bad weather or other sufficient cause for this light to be fixed, an electric torch or a lighted lantern showing a white light shall be kept at hand ready for use and shall, on the approach of an overtaking vessel, be shown in sufficient time to prevent collision.

(c) A seaplane on the water when under way shall carry on her tail a white light, so constructed as to show an unbroken light over an arc of the horizon of 140 degrees of the com-

INLAND RULES

Article 10

ART. 10 (*a*) *A vessel when underway, if not otherwise required by these rules to carry one or more lights visible from aft, shall carry at her stern a white light, so constructed that it shall show an unbroken light over an arc of the horizon of twelve points of the compass, so fixed as to show the light six points from right aft on each side of the vessel, and of such a character as to be visible at a distance of at least two miles. Such light shall be carried as nearly as practicable on the same level as the side lights.*

(*b*) *In a small vessel, if it is not possible on account of bad weather or other sufficient cause for this light to be fixed, an electric torch or a lighted lantern shall be kept at hand ready for use and shall, on the approach of an overtaking vessel, be shown in sufficient time to prevent collision.*

Not in Inland Rules.

INTERNATIONAL RULES

pass, so fixed as to show the light 70 degrees from right aft on each side of the seaplane, and of such a character as to be visible at a distance of at least 2 miles.

INLAND RULES

INTERPRETIVE RULING—INLAND RULES

86.05–5 Stern lights for all vessels.—Article 10 of section 1 of the Act of June 7, 1897, as amended by the Act of August 14, 1958 (33 U.S.C. 179), requires "a vessel when underway, if not otherwise required by these rules to carry one or more lights visible from aft, shall carry at her stern a white light, * * *" and this requirement shall be applied to all vessels, including but not limited to, tugs, barges, sail vessels, motorboats, when propelled by sail alone, etc.

COMMENT: The International Rules require a white stern light to be shown by all vessels when under way. Seaplanes on the water are also required to show a stern light.

Effective August 14, 1958, Inland Rules require "a vessel when underway, if not otherwise required by these rules to carry one or more lights visible from aft" to show the same stern light as required by the International Rules. Differences in language allow for special lights found in Inland Waters, such as the all-around after white range light.

The International Rules require an arc of visibility of 135 degrees for vessels, 140 degrees for seaplanes, and a visibility distance of 2 miles. The Inland Rules are identical for vessels. The Civil Air Regulations prescribe an arc of 140 degrees but no distance of visibility.

Another vessel should not see the stern light and the side lights of a seagoing vessel at the same time. But lights do "leak" across the limiting arc and it is possible that both may be seen. The side lights and the stern light of a seagoing vessel will probably be seen when about 2 points abaft the vessel's beam, unless so close "leaks" are on either side of the viewer.

INTERNATIONAL RULES

Rule 11 (Fig. 18.6)

(a) A vessel of less than 150 feet in length, when at anchor, shall carry in the forepart of the vessel, where it can best be seen, a white light visible all round the horizon at a distance of at least 2 miles. Such a vessel may also carry a second white light in the position prescribed in section (b) of this Rule but shall not be required to do so. The second

INLAND RULES

Article 11 (Fig. 18.6)

(a) Except as provided in paragraph (c) of this article a vessel under one hundred and fifty feet in length when at anchor shall carry forward, where it can best be seen, a white light in a lantern so constructed as to show a clear, uniform, and unbroken light visible all around the horizon at a distance of at least two miles.

INTERNATIONAL RULES

white light, if carried, shall be visible at a distance of at least 2 miles and so placed as to be as far as possible visible all round the horizon.

(b) A vessel of 150 feet or more in length, when at anchor, shall carry near the stem of the vessel, at a height of not less than 20 feet above the hull, one such light, and at or near the stern of the vessel and at such a height that it shall be not less than 15 feet lower than the forward light, another such light. Both these lights shall be visible at a distance of at least 3 miles and so placed as to be as far as possible visible all round the horizon.

(c) Between sunrise and sunset every vessel when at anchor shall carry in the forepart of the vessel, where it can best be seen, one black ball not less than 2 feet in diameter.

INLAND RULES

(*b*) *Except as provided in paragraph (c) of this article, a vessel of one hundred and fifty feet or upward in length, when at anchor, shall carry in the forward part of the vessel, at a height of not less than twenty feet above the hull, one such light, and at or near the stern of the vessel, and at such a height that it shall be not less than fifteen feet lower than the forward light, another such light.*

(*c*) *The Secretary of the Army may, after investigation, by rule, regulation, or order, designate such areas as he may deem proper as*

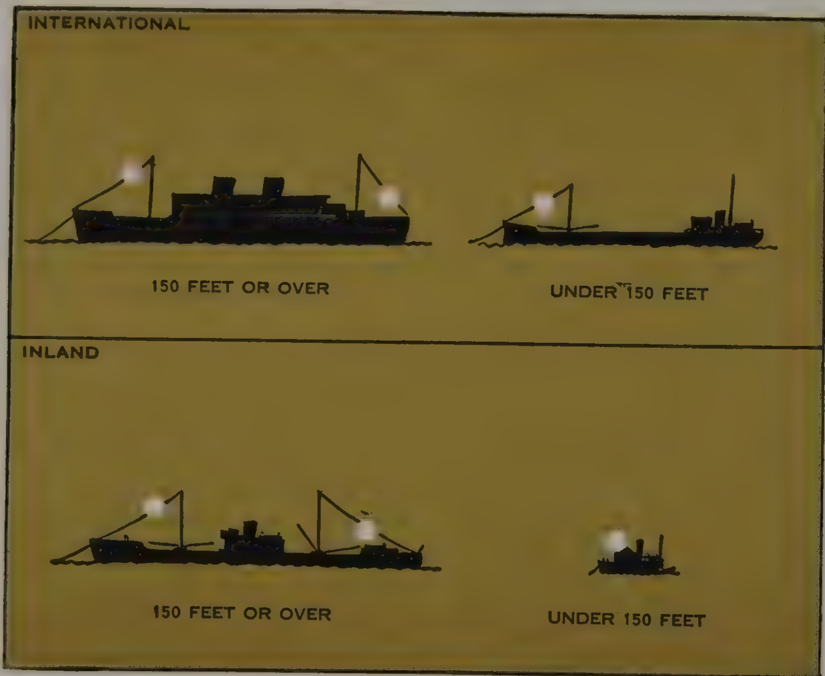


FIG. 18.6 LIGHTS ON VESSELS. Vessels at anchor.

INTERNATIONAL RULES

(d) A vessel engaged in laying or in picking up a submarine cable or navigation mark, or a vessel engaged in surveying or underwater operations, when at anchor, shall carry the lights or shapes prescribed in Rule 4(c) in addition to those prescribed in the appropriate preceding sections of this Rule.

(e) A vessel aground shall carry the light or lights prescribed in sections (a) or (b) and the two red lights prescribed in Rule 4(a). By day she shall carry, where they can best be seen, three black balls, each not less than 2 feet in diameter, placed in a vertical line one over the other, not less than 6 feet apart.

(f) A seaplane on the water under 150 feet in length, when at anchor, shall carry, where it can best be seen, a white light, visible all round the horizon at a distance of at least 2 miles.

(g) A seaplane on the water 150

INLAND RULES

"special anchorage areas"; such special anchorage areas may from time to time be changed, or abolished, if after investigation the Secretary of the Army shall deem such change or abolition in the interest of navigation. When anchored within such area—

(1) a vessel of not more than sixty-five feet in length shall not be required to carry or exhibit the white light required by this article;

(2) a barge, canal boat, scow or other nondescript craft of one hundred and fifty feet or upward in length may carry and exhibit the single white light prescribed by paragraph (a) of this article in lieu of the two white lights prescribed by paragraph (b) of this article; and

(3) where two or more barges, canal boats, scows or other nondescript craft are tied together and anchored as a unit, the anchor light prescribed by this article need be displayed only on the vessel having its anchor down.

Not in Inland Rules.

Not in Inland Rules.

Not in Inland Rules.

Not in Inland Rules.

INTERNATIONAL RULES

feet or upwards in length, when at anchor, shall carry, where they can best be seen, a white light forward and a white light aft, both lights visible all round the horizon at a distance of at least 3 miles; and, in addition, if the seaplane is more than 150 feet in span, a white light on each side to indicate the maximum span, and visible, so far as practicable, all round the horizon at a distance of 1 mile.

(h) A seaplane aground shall carry an anchor light or lights as prescribed in sections (f) and (g), and in addition may carry two red lights in a vertical line, at least 3 feet apart, so placed as to be visible all round the horizon.

INLAND RULES

Not in Inland Rules.

PILOT RULES

80.25 Vessels moored or at anchor.—Vessels of more than 65 feet in length when moored or anchored in a fairway or channel shall display between sunrise and sunset on the forward part of the vessel where it can best be seen from other vessels one black ball not less than two feet in diameter.

COMMENT: The Inland Rules allow the Secretary of the Army to designate "special anchorage areas" where vessels not more than 65 feet in length are not required to carry or exhibit an anchor light. This covers many small yachts at anchor in designated yacht anchorages in U.S. waters. In addition, nondescript vessels when at anchor in such places are permitted to show a single anchor light, irrespective of length and irrespective of whether moored singly or in a unit of several vessels.

Aircraft carriers at anchor carry a white, all-around light on each bow and quarter just below the flight deck.

The International Rules prescribe two vertical red lights and the proper anchor lights for vessels aground. The location of the grounded vessel does not affect this requirement. The Inland Rules do not prescribe special lights for grounded vessels. They should show anchor lights.

The anchor ball is required to be shown by a vessel at anchor in International and Inland waters, except that in Inland Waters such ball is not required of vessels not more than 65 feet in length.

COURT DECISIONS: "No rule required the launch (secured to a man-of-war's boat boom) to exhibit any additional light nor did the boom project an unusual or unreasonable distance (nearly 60 feet) for such a ship. . . ." (THE DIMITRI DONSKOI, 60 F 111.)

A vessel secured alongside another vessel at anchor must show the proper anchor lights. (THE PRUDENCE, 197 F 479.)

There are no rules, International or Inland, requiring a vessel moored to a wharf to show anchor lights. "It is not the practice to exhibit such (anchor) lights unless there are some special circumstances of danger, having reference to the ordinary navigation of other vessels." (HADDEN *v.* J. H. RUTTER, 35 F 365.) Anchor lights should be shown if custom requires it (SHIELDS *v.* THE MAYOR, 18 F 748), or if the vessel or any part of her projects near to the usual courses of passing vessels. (INDUSTRY, 27 F 767.)

If a vessel obstructs a slip by a line stretched across or by any other unusual obstruction, a light should be shown to warn entering vessels. (FULDA, 31 F 351.)

INTERNATIONAL RULES

Rule 12

Every vessel or seaplane on the water may, if necessary in order to attract attention, in addition to the lights which she is by these Rules required to carry, show a flare-up light or use a detonating or other efficient sound signal that cannot be mistaken for any signal authorized elsewhere under these Rules.

INLAND RULES

Article 12

ART. 12. *Every vessel may, if necessary, in order to attract attention, in addition to the lights which she is by these rules required to carry, show a flare-up light or use any detonating signal that cannot be mistaken for a distress signal.*

COMMENT: The International Rules provide three methods of attracting attention: (a) a flare-up, (b) a detonating signal, and (c) an efficient sound signal. The Inland Rules provide the first two methods but not the sound signal.

The use in International waters of efficient sound signal, i.e., a whistle, consisting of short, rapid blasts is inadvisable as such blasts show either a change in course, presence of a pilot vessel, or a doubt that sufficient action is being taken by the other vessel to avert collision (see Rules 15 and 28). The use of these signals is optional. (THE PACIFIC, 154 F 943.)

INTERNATIONAL RULES

Rule 13

(a) Nothing in these Rules shall interfere with the operation of any special rules made by the Government of any nation with respect to additional station and signal lights for ships of war, for vessels sailing under convoy, for fishing vessels engaged in fishing as a fleet or for seaplanes on the water.

INLAND RULES

Article 13

ART. 13. *Nothing in these rules shall interfere with the operation of any special rules made by the Government of any nation with respect to additional station and signal lights for two or more ships of war or for vessels sailing under convoy, or with the exhibition of recognition signals adopted by shipowners, which have been authorized by their respective*

INTERNATIONAL RULES	*INLAND RULES*
(b) Whenever the Government concerned shall have determined that a naval or other military vessel or water-borne seaplane of special construction or purpose cannot comply fully with the provisions of any of these Rules with respect to the number, position, range or arc of visibility of lights or shapes, without interfering with the military function of the vessel or seaplane, such vessel or seaplane shall comply with such other provisions in regard to the number, position, range or arc of visibility of lights or shapes as her Government shall have determined to be the closest possible compliance with these Rules in respect of that vessel or seaplane.	*Governments, and duly registered and published.* *Not in Inland Rules.* (*But, Act of December 3, 1945, as amended, which is applicable to Inland Waters, is similar with respect to lights.*)

COMMENT: This International Rule allows naval vessels, vessels sailing under convoy, vessels fishing in formation or seaplanes on the water to show additional station and signal lights. It does not exempt these vessels from showing the usual navigation lights. Subparagraph (b) of the International Rules has already been covered by enacting clauses of the International Rules (see Chapter 16).

INTERNATIONAL RULES	*INLAND RULES*
Rule 14	***Article 14***
A vessel proceeding under sail, when also being propelled by machinery, shall carry in the daytime forward, where it can best be seen, one black conical shape, point downwards, not less than 2 feet in diameter at its base.	ART. 14. *A steam vessel proceeding under sail only, but having her funnel up, may carry in daytime, forward, where it can best be seen, one black ball or shape two feet in diameter.*

COMMENT: The International Rule deals with a vessel proceeding under sail when also being propelled by machinery. The Inland Rule affects a steam vessel proceeding under sail only but having her funnel up. The latter is thus obsolete.

The distinguishing shape is a black cone, point down in International Waters, and a black ball or shape in Inland Waters.

19

Fog Signals, Rules 15, 16

INTERNATIONAL RULES

PART C—SOUND SIGNALS AND CONDUCT IN RESTRICTED VISIBILITY

Preliminary

1. *The possession of information obtained from radar does not relieve any vessel of the obligation of conforming strictly with the Rules and, in particular, the obligations contained in Rules 15 and 16.*

2. *The Annex to the Rules contains recommendations intended to assist in the use of radar as an aid to avoiding collision in restricted visibility.*

Rule 15 (Figs. 19.1 to 19.3)

(a) A power-driven vessel of 40 feet or more in length shall be provided with an efficient whistle, sounded by steam or by some substitute for steam, so placed that the sound may not be intercepted by any obstruction, and with an efficient fog-horn, to be sounded by mechanical means, and also with an efficient bell. A sailing vessel of 40 feet or more in length shall be provided with a similar fog-horn and bell.

(b) All signals prescribed in this Rule for vessels under way shall be given:

(i) by power-driven vessels on the whistle;

(ii) by sailing vessels on the fog-horn;

(iii) by vessels towed on the whistle or fog-horn.

(c) In fog, mist, falling snow,

INLAND RULES

III. SOUND SIGNALS FOR FOG, AND SO FORTH

Not in Inland Rules.

Article 15 (Figs. 19.1 to 19.3)

ART. 15. *All signals prescribed by this article for vessels under way shall be given:*

1. By "steam vessels" on the whistle or siren.

2. By "sailing vessels" and "vessels towed" on the fog horn.

The words "prolonged blast" used in this article shall mean a blast of from four to six seconds' duration.

A steam vessel shall be provided with an efficient whistle or siren, sounded by steam or by some substitute for steam, so placed that the sound may not be intercepted by any obstruction, and with an efficient fog horn; also with an efficient bell. A sailing vessel of twenty tons gross tonnage or upward shall be provided with a similar fog horn and bell.

In fog, mist, falling snow, or heavy rain storms, whether by day or night,

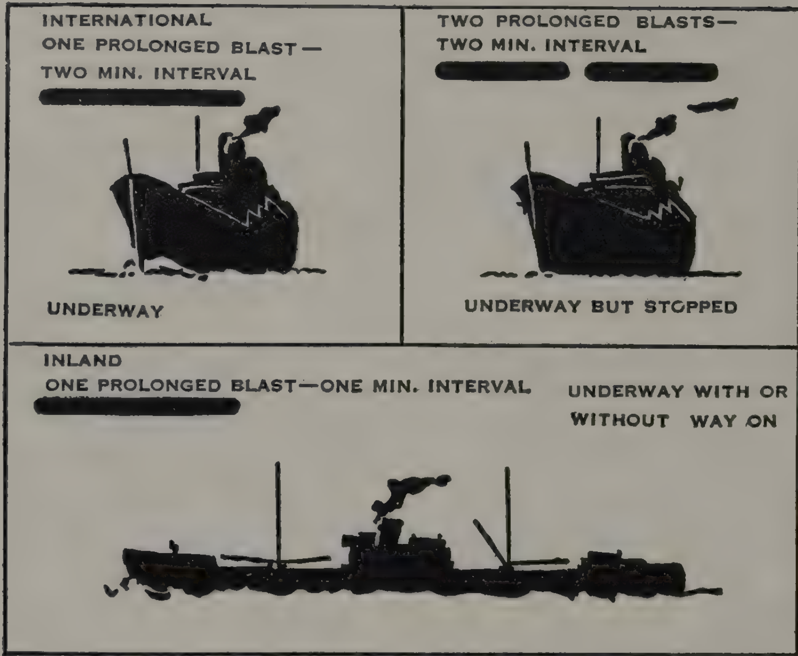


FIG. 19.1 SOUND SIGNALS IN THICK WEATHER. Steam vessels under way.

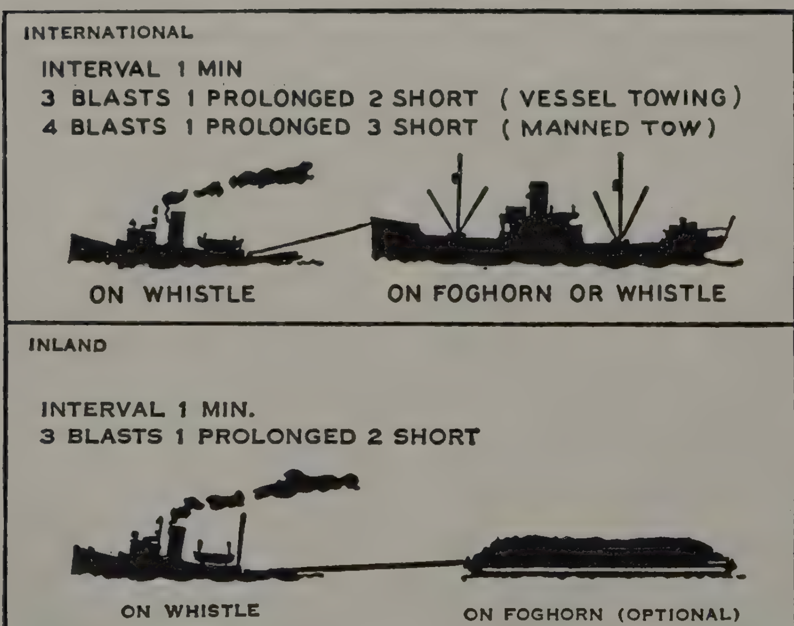


FIG. 19.2 SOUND SIGNALS IN THICK WEATHER. Vessels towed or towing.

INTERNATIONAL RULES

heavy rainstorms, or any other condition similarly restricting visibility, whether by day or night, the signals prescribed in this Rule shall be used as follows:

(i) A power-driven vessel making way through the water, shall sound at intervals of not more than 2 minutes a prolonged blast.

INLAND RULES

the signals described in this article shall be used as follows, namely:

(*a*) *A steam vessel under way shall sound, at intervals of not more than one minute, a prolonged blast.*

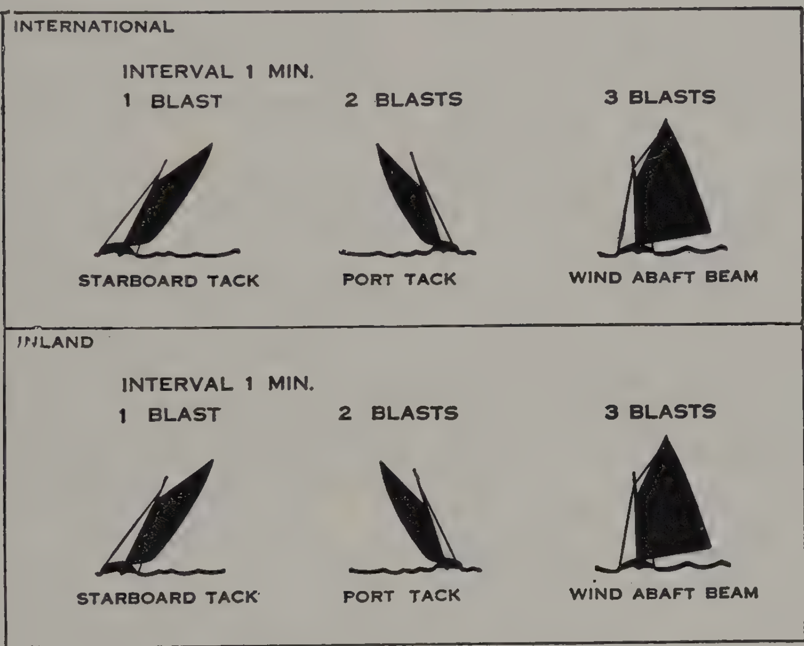


FIG. 19.3 SOUND SIGNALS IN THICK WEATHER. Sail vessels under way.

(ii) A power-driven vessel under way, but stopped and making no way through the water, shall sound at intervals of not more than 2 minutes two prolonged blasts, with an interval of about 1 second between them.

(iii) A sailing vessel under way shall sound, at intervals of not more than 1 minute, when on the starboard tack one blast, when on the port tack two blasts in succession, and when with the wind abaft the beam three blasts in succession.

(*b*) *Not in Inland Rules.*

(*c*) *A sailing vessel under way shall sound, at intervals of not more than one minute, when on the starboard tack, one blast; when on the port tack, two blasts in succession, and when with the wind abaft the beam, three blasts in succession.*

INTERNATIONAL RULES

(iv) A vessel when at anchor shall at intervals of not more than 1 minute ring the bell rapidly for about 5 seconds. In vessels of more than 350 feet in length the bell shall be sounded in the forepart of the vessel, and in addition there shall be sounded in the after part of the vessel, at intervals of not more than 1 minute for about 5 seconds, a gong or other instrument, the tone and sounding of which cannot be confused with that of the bell. Every vessel at anchor may in addition, in accordance with Rule 12, sound three blasts in succession, namely, one short, one prolonged, and one short blast, to give warning of her position and of the possibility of collision to an approaching vessel.

(v) A vessel when towing, a vessel engaged in laying or in picking up a submarine cable or navigation mark, and a vessel under way which is unable to get out of the way of an approaching vessel through being not under command or unable to manoeuvre as required by these Rules shall, instead of the signals prescribed in subsections (i), (ii) and (iii) sound, at intervals of not more than 1 minute, three blasts in succession, namely, one prolonged blast followed by two short blasts.

(vi) A vessel towed, or, if more than one vessel is towed, only the last vessel of the tow, if manned, shall, at intervals of not more than 1 minute, sound four blasts in succession, namely, one prolonged blast followed by three short blasts. When practicable, this signal shall be made immediately after the signal made by the towing vessel.

(vii) A vessel aground shall give the bell signal and, if required, the gong signal, prescribed in subsection (iv) and shall, in addition, give three separate and distinct strokes on the bell immediately before and after such rapid ringing of the bell.

INLAND RULES

(d) A vessel when at anchor shall, at intervals of not more than one minute, ring the bell rapidly for about five seconds, except that the following vessels shall not be required to sound this signal when anchored in a special anchorage area established pursuant to Article 11(c).

(1) a vessel of not more than sixty-five feet in length; and

(2) a barge, canal boat, scow, or other nondescript craft.

(e) A steam vessel when towing, shall, instead of the signals prescribed in subdivision (a) of this article, at intervals of not more than one minute, sound three blasts in succession, namely, one prolonged blast followed by two short blasts. A vessel towed may give this signal and she shall not give any other.

Not in Inland Rules.

INTERNATIONAL RULES	*INLAND RULES*
(viii) A vessel engaged in fishing when under way or at anchor shall at intervals of not more than 1 minute sound the signal prescribed in subsection (v). A vessel when fishing with trolling lines and under way shall sound the signals prescribed in subsections (i), (ii) or (iii) as may be appropriate.	*Not in Inland Rules.*
(ix) A vessel of less than 40 feet in length, a rowing boat, or a seaplane on the water, shall not be obliged to give the above-mentioned signals, but if she does not, she shall make some other efficient sound signal at intervals of not more than 1 minute.	(*f*) *All rafts or other water craft, not herein provided for, navigating by hand power, horse power, or by the current of the river, shall sound a blast of the fog horn, or equivalent signal, at intervals of not more than one minute.*
(x) A power-driven pilot-vessel when engaged on pilotage duty may, in addition to the signals prescribed in subsections (i), (ii) and (iv), sound an identity signal consisting of 4 short blasts.	*Not in Inland Rules.*

PILOT RULES

80.12 Fog signals.—In fog, mist, falling snow, or heavy rainstorms, whether by day or night, signals shall be given as follows:

(a) A steam vessel under way, except when towing other vessels or being towed, shall sound, at intervals of not more than 1 minute, on the whistle or siren, a prolonged blast.

(b) A steam vessel when towing other vessels shall sound, at intervals of not more than 1 minute, on the whistle or siren, three blasts in succession, namely, one prolonged blast followed by two short blasts.

(c) A vessel towed may give, at intervals of not more than 1 minute, on the fog horn, a signal of three blasts in succession, namely, one prolonged blast followed by two short blasts, and she shall not give any other.

(d) A vessel when at anchor shall, at intervals of not more than 1 minute, ring the bell rapidly for about 5 seconds.

ACT OF APRIL 25, 1940; EXCERPTS FROM

AN ACT TO AMEND LAWS FOR PREVENTING COLLISIONS OF VESSELS, TO REGULATE THE EQUIPMENT OF CERTAIN MOTORBOATS ON THE NAVIGABLE WATERS OF THE UNITED STATES, AND FOR OTHER PURPOSES

Whistles

SEC. 4. Every motorboat of class 1, 2, or 3 shall be provided with an efficient whistle or other sound-producing mechanical appliance. (*46 U.S.C. 526c.*)

Bells

Sec. 5. Every motorboat of class 2 or 3 shall be provided with an efficient bell. (*46 U.S.C. 526d.*)

* * * * * * *

Exemptions for outboard racing motorboats

Sec. 9. The provisions of sections 4, 5, . . . of this Act shall not apply to motorboats propelled by outboard motors while competing in any race previously arranged and announced or, if such boats be designed and intended solely for racing, while engaged in such navigation as is incidental to the tuning up of the boats and engines for the race. *(46 U.S.C. 526h.)*

Comment: The International and Inland (Pilot) Rules require power-driven and steam vessels to sound fog signals on a whistle, sounded by steam or some substitute for steam. The word "whistle" as defined in International Rules includes a siren. In Inland Rules where "whistle" is undefined, use of a siren is provided for. To the listener, the only difference between the two is that a siren has a more shrill tone than a whistle.

Both Rules require sailing vessels to use a foghorn.

The International Rules require vessels towed to sound fog signals on the whistle or foghorn, but the Inland and Pilot Rules prescribe the foghorn.

The International Rules go a step farther than the Inland Rules about the conditions under which fog signals must be sounded. They state that fog signals shall be used not only in fog, mist, falling snow, heavy rainstorms, as required by Inland Rules, but also in "any other condition similarly restricting visibility." The Courts have ruled that statutory (Inland) rules apply to any obscuration of the air, such as smoke. (THE YOSEMITE, 28 F 2d, 939.) Fog signals should therefore be sounded in smoke or sandstorms in both waters if visibility is restricted.

Both the International and Inland Rules require a power-driven (steam) vessel in a fog to sound a prolonged blast. The interval is different under these two Rules—not more than 2 minutes in International Waters and not more than 1 minute in Inland Waters. The International Rules contains an additional paragraph, 15(c) (ii), which requires "a power-driven vessel under way but stopped and making no way through the water" to sound two prolonged blasts at intervals of not more than 2 minutes.

The International Rules prescribe the same fog signal for sailing vessels as the Inland Rules and at the same interval, not more than 1 minute.

The International Rules provide an additional fog signal for vessels more than 350 feet in length when at anchor. They are required to sound a gong or other instrument, aft, in addition to the fog bell forward. The International Rules also prescribe an additional fog signal which may be sounded by a vessel at anchor in a fog to give warning of her position and of the possibility of collision—one short, one prolonged, and one short blast. The Inland Rules neither recognize long vessels nor provide such a warning fog signal.

The International Rules have improved on the Inland Articles which prescribe a distinctive fog signal for steam vessels when towing, by applying the Rule to *all* vessels and by including "a vessel engaged in laying or in picking up a submarine cable or navigation mark, and a vessel under way which is unable to get out of the way of an approaching vessel through being not under command or unable to maneuver." Thus, a sailing vessel under way in International waters in a fog but unable to get out of the way of an approaching vessel because she is becalmed or is not under command should sound one prolonged blast followed by two short blasts. These additional steam vessels can only sound the prolonged blast or one, two or three blasts, if sailing vessels, under Inland Rules.

The International Rules require "a vessel towed or, if more than one vessel is towed, the last vessel of the tow, if manned, to sound a new, distinctive fog signal, one prolonged blast, followed by three short blasts." The Inland Rules permit but do not require towed vessels to sound three blasts in succession, one prolonged followed by *two* short blasts.

The International Rules contain a special rule for a vessel aground. She is required to sound the usual at anchor fog signals and "in addition, three separate and distinct strokes on the bell immediately before and after each such signal." The Inland Rules do not have a distinctive fog signal for a vessel aground. The Courts have ruled that distress signals, i.e., a continuous sounding with any fog-signaling apparatus, is proper for a vessel aground in Inland Waters. (THE LEVIATHAN, 286 F 745.)

New International Rule 15(c) (viii) contains a new fog signal for fishing vessels. A vessel fishing as defined in the Rules now gives the same signal as a vessel towing or a vessel unable to get out of the way, whether under way or at anchor. In Inland Waters vessels fishing give signals prescribed for vessels of their class at all times.

Another new International Rule, Rule 15(c) (x), authorizes Pilot vessels on duty to sound four short blasts as an identity signal. However, in both waters Pilot vessels must give signals for vessels of their class.

In the case of the QUEVILLY, 253 F 415, a vessel was found at fault because she did not increase the frequency of her fog signal when proceeding through an anchorage.

LA BOYTEAUX suggests that fog signals should be started before the visibility has dropped to 2 miles which is the distance side lights must be visible.

Naval and some merchant vessels may use an automatic fog whistle. When no vessel is heard in the vicinity, it is a convenient, labor-saving device. After the fog whistle or horn of an approaching vessel is heard, the "automatic" should be shifted to "hand." Thereafter, the fog signal should be sounded more frequently but not immediately after the fog signal of the other vessel.

Both rules are so worded that vessels in or near fog shall sound only fog signals while they are not in sight of each other. There is one exception. Under the Inland and Pilot Rules the danger signal may be sounded when in doubt

as to the course or intention of the other vessel, even though she is not in sight in the fog. (THE VIRGINIAN, 238 F 156.)

Fog distorts, suppresses, and changes the direction of fog signals at times.

The International and Inland Rules require large power-driven (steam) vessels to be provided with an efficient whistle, foghorn, and bell. Both Rules also require large sailing vessels to be provided with an efficient foghorn and bell. Only the International Rules require these vessels to sound their foghorns by mechanical means.

Small vessels in both waters are required to give the fog signals prescribed for larger vessels of their type if equipped with appropriate sound devices. In International Waters where sound equipment is not required of vessels under 40 feet in length, the Rules provide for an effective substitute signal at intervals of not more than one minute. In Inland Waters the Motorboat Act of 1940 has amended the Inland Rules in the case of sound apparatus, but not fog signals. The net effect is to make Article 15(f) applicable to small vessels not equipped with appropriate sound devices. In both waters it is best to have the necessary sound devices and to give the prescribed fog signals.

COURT DECISIONS: The International Rules require the last vessel of a tow, if manned, to sound a distinctive fog signal. The Inland Rules allow but do not require a vessel towed to sound the same signal as the towing steam vessel. A tow in Inland Waters need not sound a fog signal at all times in a fog, but it should do so when the circumstances make it desirable to indicate its location. The tow should sound it when it is in crowded waters or when the tow is long. (OPHELIA, 44 F 941.)

Naval vessels are not exempted from sounding fog signals even in war. They may not do so but, if a collision results, they may be found in fault. (WATTS *v.* U.S., 123 F 105)

The Courts have not ruled the kinds of whistles and horns that are efficient, but they have ruled in definite cases that the fog-signaling apparatus was not efficient.

A steamer which left port with her whistle "out of commission" and which sounded a foghorn and not a whistle was held at fault. (THE MINNESOTA, 189 F 706.)

"A vessel is under obligation to observe the rule (sounding fog signals) not only when she is actually enveloped in the fog, but also when she is so near it that it is necessary that her position should be known to every vessel that may happen to be within it." (THE PERKIOMEN, 27 F 573.)

A vessel which is lying alongside a pier not projecting beyond the end of the pier into the stream is not required to sound fog signals. (THE EXPRESS, 48 F 323.)

A court has held recently that a radar-equipped vessel was in fault for entering a fog bank without using her radar. (THE MEDFORD, 65 F Supp. 622.)

When a tow is anchored, proper signals must be given by each vessel (at least by each vessel on the outside of a tier). The tug, if present, is responsible.

(THE RALEIGH, 44 F 781). If the tug is not present, the tow is responsible. (JERSEY CENTRAL, 221 F 625).

The law requires every vessel at anchor in a group to sound a fog signal. (COHOCTON, 299 F 319.)

SUMMARY OF FOG SIGNALS

Type of vessel	International rules		Inland rules	
	Signal	Maximum interval	Signal	Maximum interval
Power-driven or steam vessel under way making way through water	—	2 min	—	1 min
Power-driven or steam vessel, under way but stopped and making no way through water	— —	2 min	—	1 min
Vessel towing	—• •	1 min	—• •	1 min
Vessel laying submarine cable or navigation mark	—• •	1 min	—	1 min
Vessel not under command	—• •	1 min	—	1 min
Vessel towed †	—• • •	1 min	—• •	1 min
Vessel at anchor	*	1 min	*	1 min
Vessel aground	0 * 0	1 min	*	1 min
Sailing vessel				
On starboard tack	—	1 min	—	1 min
On port tack	— —	1 min	— —	1 min
Wind abaft beam	— — —	1 min	— — —	1 min
Vessels fishing, under way or at anchor	—• •	1 min	—	1 min
Pilot vessel on duty ‡	• • • •			

0 represents three strokes of bell.

* represents bell, forward, 5 seconds, except International Waters, where vessels over 350 feet sound gong aft also.

— represents a prolonged blast.

• represents a short blast.

† Optional, Inland. Single vessel, or last vessel of tow, International, *when* manned.

‡ Optional identity signal International waters which may be given in addition to signals required when under way or at anchor. By court decision this signal can be used in Inland waters as a danger signal.

Sounding of gong aft applies only to vessels of more than 350 feet in length at anchor or aground in International waters. Vessels at anchor in International Waters may also sound a three-blast signal, one short, one prolonged, one short at unspecified intervals as a collision warning.

INTERNATIONAL RULES

Rule 16

(a) Every vessel, or seaplane when taxi-ing on the water, shall, in fog, mist, falling snow, heavy rainstorms or any other condition similarly restricting visibility, go at a moderate speed, having careful re-

INLAND RULES

Article 16

ART. 16. *Every vessel shall, in a fog, mist, falling snow, or heavy rain storms, go at a moderate speed, having careful regard to the existing circumstances and conditions.*

A steam vessel hearing, apparently

INTERNATIONAL RULES

gard to the existing circumstances and conditions.

(b) A power-driven vessel hearing, apparently forward of her beam, the fog-signal of a vessel the position of which is not ascertained, shall, so far as the circumstances of the case admit, stop her engines, and then navigate with caution until danger of collision is over.

(c) A power-driven vessel which detects the presence of another vessel forward of her beam before hearing her fog signal or sighting her visually may take early and substantial action to avoid a close quarters situation but, if this cannot be avoided, she shall, so far as the circumstances of the case admit, stop her engines in proper time to avoid collision and then navigate with caution until danger of collision is over.

INLAND RULES

forward of her beam, the fog signal of a vessel the position of which is not ascertained shall, so far as the circumstances of the case admit, stop her engines, and then navigate with caution until danger of collision is over.

Not in Inland Rules.

PILOT RULES

80.13 Speed in fog; pamphlet containing pilot rules; diagrams—(a) Moderate speed in fog.—Every steam vessel shall, in a fog, mist, falling snow, or heavy rain storms, go at a moderate speed, having careful regard to the existing circumstances and conditions.

(b) A steam vessel hearing, apparently forward of her beam, the fog signal of a vessel the position of which is not ascertained shall, so far as the circumstances of the case admit, stop her engines and then navigate with caution until danger of collision is over.

ANNEX TO INTERNATIONAL RULES

RECOMMENDATIONS ON THE USE OF RADAR INFORMATION AS AN AID TO AVOIDING COLLISIONS AT SEA

(1) Assumptions made on scanty information may be dangerous and should be avoided.

(2) A vessel navigating with the aid of radar in restricted visibility must, in compliance with Rule 16(a), go at a moderate speed. Information obtained from the use of radar is one of the circumstances to be taken into account when determining moderate speed. In this regard it must be recognized that small vessels, small icebergs and similar floating objects may not be detected by radar. Radar indications of one or more vessels in the vicinity may mean

that "moderate speed" should be slower than a mariner without radar might consider moderate in the circumstances.

(3) When navigating in restricted visibility the radar range and bearing alone do not constitute ascertainment of the position of the other vessel under Rule 16(b) sufficiently to relieve a vessel of the duty to stop her engines and navigate with caution when a fog signal is heard forward of the beam.

(4) When action has been taken under Rule 16(c) to avoid a close quarters situation, it is essential to make sure that such action is having the desired effect. Alterations of course or speed or both are matters as to which the mariner must be guided by the circumstances of the case.

(5) Alteration of course alone may be the most effective action to avoid close quarters provided that:—

(a) There is sufficient sea room.

(b) It is made in good time.

(c) It is substantial. A succession of small alterations of course should be avoided.

(d) It does not result in a close quarters situation with other vessels.

(6) The direction of an alteration of course is a matter in which the mariner must be guided by the circumstances of the case. An alteration to starboard, particularly when vessels are approaching apparently on opposite or nearly opposite courses, is generally preferable to an alteration to port.

(7) An alteration of speed, either alone or in conjunction with an alteration of course, should be substantial. A number of small alterations of speed should be avoided.

(8) If a close quarters situation is imminent, the most prudent action may be to take all way off the vessel.

COMMENT: Masters of vessels in collision have pleaded a variety of excuses to prove that their speed was moderate under the existing conditions and circumstances. These excuses have included maneuverability, schedules, inability to slow down, and carrying U.S. mails. These excuses have seldom been accepted. Recently, they have pleaded radar, with no greater success. The courts have not been sympathetic to arguments that radar justifies a speed over that considered moderate for a vessel without radar or, for that matter, neglect, for that reason, of any other requirement set forth in the rules. The sense of the decisions has been that radar should be used with, not in lieu of, Rules (Arts.) 15 and 16, and that Rule (Art.) 29 should ever be borne in mind. The latter states: "Nothing in these Rules shall exonerate any vessel, or the owner, master or crew thereof, from the consequences of any neglect to carry lights or signals, or of any neglect to keep a proper lookout, or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case."

The sense of the court decisions has been incorporated in the International Rules, 1960 (Preliminary) and the Annex to the International Rules, 1960,

above, containing "Recommendations on the use of Radar information as an aid to avoiding collisions at sea." These recommendations contain prudent principles of seamanship and should be used as a guide in Inland waters where the Rules are silent on Radar.

Rule 16(c) is a new addition to the International Rules. It should be applied with prudence in full accord with the Radar recommendations.

COURT DECISIONS: The courts have handed down many decisions defining moderate speed. They may be condensed into two specific rulings: ". . . a steamer is bound to use only such precautions as will enable her to stop in time to avoid a collision, after the approaching vessel comes in sight, providing such approaching vessel is herself going at a moderate speed required by law." (THE UMBRIA, 166 U.S. 404.)

Again, the Circuit Court of Appeal, 9th District, ruled in the CHICAGO, 94 F 2d 754, that "one of the very long established principles of law in maritime navigation is that a vessel shall not proceed in a fog at a speed at which she cannot be stopped dead in the water in one half of the visibility before her."

The use of radar will not excuse immoderate speed as interpreted under Rule (Art.) 16, nor will it serve as an excuse for noncompliance with the Rules. (ARGENTINA—ANTINOUS, 1957 AMC 2356.)

"Radar is an aid, not a substitute, for prudent seamanship. . . ." (THE BUCENTAUR—THE WILSON VICTORY, 125 F Supp 42, 1955 AMC 142.)

"Prudent navigation involves taking advantage of all safety devices at hand. . . ." (THE HINDOO—THE AUSTRALIA STAR, 172 F 2d 472, 338 U.S. 823.)

The phrase in the Rule "having careful regard to the existing circumstances and conditions" comprises density of fog, nearby rocks and shoals, probability of encountering other vessels, vessels in company, known positions of anchored vessels, fog signals heard, channels, and many other conditions.

The Rule regarding moderate speed applies to sailing vessels as well as steamers. (ADAMS *v.* U.S., D.C. Mass. 1921.)

". . . These rules [Article 16] govern the navigation of a war vessel in time of war. . . ." (N.Y. AND CUBA MAIL S.S. CO. *v.* U.S., D.C. S.D. N.Y. 1924.)

The courts have ruled vessels at fault for leaving a safe berth in a fog. (THE GEORGIA, 208 F 635, 642.)

"In a dense fog it is the duty of a steam vessel to anchor in a permissible anchorage as soon as the circumstances permit; but there is no absolute duty to anchor in a thoroughfare. . . ." (THE MOHEGAN, 28 F 2d 795.)

U.S. Code Title 33, Sec. 409, forbids vessels to anchor "in navigable channels in such a manner as to prevent or obstruct the passage of other vessels. . . ." But there is no rule which forbids a vessel to anchor in a channel in a fog, unless she obstructs navigation. (THE QUIRIGUA, 93 F 2d 297.)

The court in the CITY OF NORFOLK, 266 F 641, ruled that a vessel caught in a dense fog and anchoring in the channel because in her master's best judgment it was safer than to attempt to reach another anchorage does not violate the statute and is not at fault.

In the case of THE GEORGIA, 208 F 635, the court ruled: "While it may be reasonable to say that the statute does not absolutely prohibit anchoring in navigable channels or make it a fault to anchor where controlling conditions make it absolutely necessary, yet the question whether a vessel is anchored in such a manner as to prevent or obstruct the passage of other vessels must be determined by looking not alone to the chart and to the geography of the situation but also to weather conditions and to the usual course of vessels using the thoroughfare." A vessel should anchor usually in designated anchorage areas in a fog. (THE RICHMOND, 63 F 1020.)

"The presumption, where a moving vessel comes into collision with one at anchor, in a fog, and where there is no evidence of negligence on the part of the anchored vessel, is, by well established rule, against the moving vessel." (THE CANANOVA, 297 F 658.)

"The INDRAKUALA should at least have slowed down upon approaching and entering the fog. . . ." (THE JULIA LUCKENBACH *v.* INDRAKUALA, 219 F 600.)

The courts have ruled many times that a steam vessel must stop her engines as far as the circumstances permit when she hears, forward of her beam, the fog signal of a vessel, the position of which is not ascertained. (THE SENECA, D.C. S.D. N.Y. 1908.) They have also ruled that a steamer should reduce her headway by reversing her engines in order to navigate with caution. (THE CITY OF ATLANTA, 26 F 456.)

"The notion that a ship, equipped with radar, may, once her navigation and range lights are bright, plunge through the seas at 15 knots in the hope that all other craft will keep clear of it cannot be accepted as a rule of safe and prudent navigation. . . ." (THE HINDOO—THE AUSTRALIA STAR, 172 F 2d 472, 338 U.S. 823.)

The apparent distance of the foghorn does not change the rule to stop the engines at once. Fog affects the sound of fog whistles and horns adversely. (LIE *v.* SAN FRANCISCO & PORTLAND S.S. CO., 243 U.S. 291.) The phrase "the position of which is not ascertained" has been ruled to include a knowledge of the position, i.e., the distance, direction, and course of the approaching vessel. (THE TREMONT, 160 F 1016.)

"It may be that proper observations on a PPI (i.e., radar scope) can 'ascertain' the position of a vessel. . . . They clearly did not do so in this case. . . ." (THE PRINS ALEXANDER, 2 Lloyds' List L.R.I.)

The courts have also ruled that the custom of some masters of porting the helm (turning right) when a fog signal is heard ahead is not navigating with caution. (THE COUNSELLOR (1913), Prob. Div. 70.)

Sailing vessels are not required to stop when a fog signal is heard forward of the beam. They are required to proceed at a moderate speed in a fog. (THE CHATTAHOOCHEE, 173 U.S. 540.)

There is no right of way in a fog while the vessels are not in sight. The Steering and Sailing Rules do not apply until the vessels are in sight. If the vessels are then so close that both must take action to avoid collision, Article

27 applies. If there is room to maneuver in accordance with the Steering and Sailing Rules, the proper whistle signals should be sounded and the latter Rules obeyed.

"Scientific installations, and particularly radar, are potentially most valuable instruments for increasing safety at sea, but they only remain valuable if they are intelligently used, and if the officers responsible for working them work them and interpret them with intelligence. . . ." (THE ANNA SALEM, 1954, 1 Lloyds' List L.R. 475.)

20

Steering and Sailing Rules, Rules (Articles) 17–27

INTERNATIONAL RULES

PART D—STEERING AND SAILING RULES

Preliminary

1. In obeying and construing these Rules, any action taken should be positive, in ample time, and with due regard to the observance of good seamanship.

2. Risk of collision can, when circumstances permit, be ascertained by carefully watching the compass bearing of an approaching vessel. If the bearing does not appreciably change, such risk should be deemed to exist.

3. Mariners should bear in mind that seaplanes in the act of landing or taking off, or operating under adverse weather conditions, may be unable to change their intended action at the last moment.

4. Rules 17 to 24 apply only to vessels in sight of one another.

INLAND RULES

PART IV—STEERING AND SAILING RULES

Preliminary—Risk of Collision

Not in Inland Rules.

Same as International Rules.

Not in Inland Rules.

PILOT RULES

80.02 Definition of steam vessel and vessel under way; risk of collision.—In the rules in this part the words "steam vessel" shall include any vessel propelled by machinery. A vessel is under way, within the meaning of the rules in this part, when she is not at anchor, or made fast to the shore, or aground. Risk of collision can, when circumstances permit, be ascertained by carefully watching the compass bearing of an approaching vessel. If the bearing does not appreciably change, such risk should be deemed to exist.

COMMENT: These are not compulsory rules, only suggestions that the risk of collision may be ascertained, with some certainty, by watching the compass bearing. They should be heeded, nevertheless. The bearing should be taken

at adequate distance on a sharply defined point and repeated at frequent intervals until the vessels are safely past each other. The Rules require both vessels to take particular, prescribed actions when risk of collision is involved. A constant or nearly constant bearing is one indicator. It is obvious that the risk of collision does not exist when the two vessels are so far apart that a change in speed or course of either does not affect the other. However, such vessels may be on converging courses and speeds which will bring them dangerously close. One or both vessels may also change course or speed with the same result. When the two vessels have reached a point where a change in speed or course of one does affect the movements of the other and when the bearing is not changing, then a risk of collision is involved, and timely action must be taken. The Courts have handed down many rulings on this subject. One of these rulings has already been quoted, see Chapter 15, Risk of Collision. For further comment, see Rule 19.

Three final cautions are desirable:

1. Very gradually changing compass bearings should be watched suspiciously.
2. Comply with the Rules while there is yet time for each to understand the proposed movements of the other and to take the action prescribed by the Rules.
3. If a change of course is required by the Rules, it should be large enough to be noticeable by the other vessel.

INTERNATIONAL RULES

Rule 17 (Fig. 20.1)

(a) When two sailing vessels are approaching one another, so as to involve risk of collision, one of them shall keep out of the way of the other, as follows:

(i) When each has the wind on a different side, the vessel which has the wind on the port side shall keep out of the way of the other.

(ii) When both have the wind on the same side, the vessel which is to windward shall keep out of the way of the vessel which is to leeward.

(b) For the purposes of this Rule the windward side shall be deemed to be the side opposite to that on which the mainsail is carried or, in the case of a square-rigged vessel, the side opposite to that on which the largest fore-and-aft sail is carried.

INLAND RULES

Article 17 (Fig. 20.1)

ART. 17. *When two sailing vessels are approaching one another, so as to involve risk of collision, one of them shall keep out of the way of the other as follows, namely:*

(*a*) *A vessel which is running free shall keep out of the way of a vessel which is closehauled.*

(*b*) *A vessel which is closehauled on the port tack shall keep out of the way of a vessel which is closehauled on the starboard tack.*

(*c*) *When both are running free, with the wind on different sides, the vessel which has the wind on the port side shall keep out of the way of the other.*

(*d*) *When both are running free, with the wind on the same side, the vessel which is to the windward shall keep out of the way of the vessel which is to the leeward.*

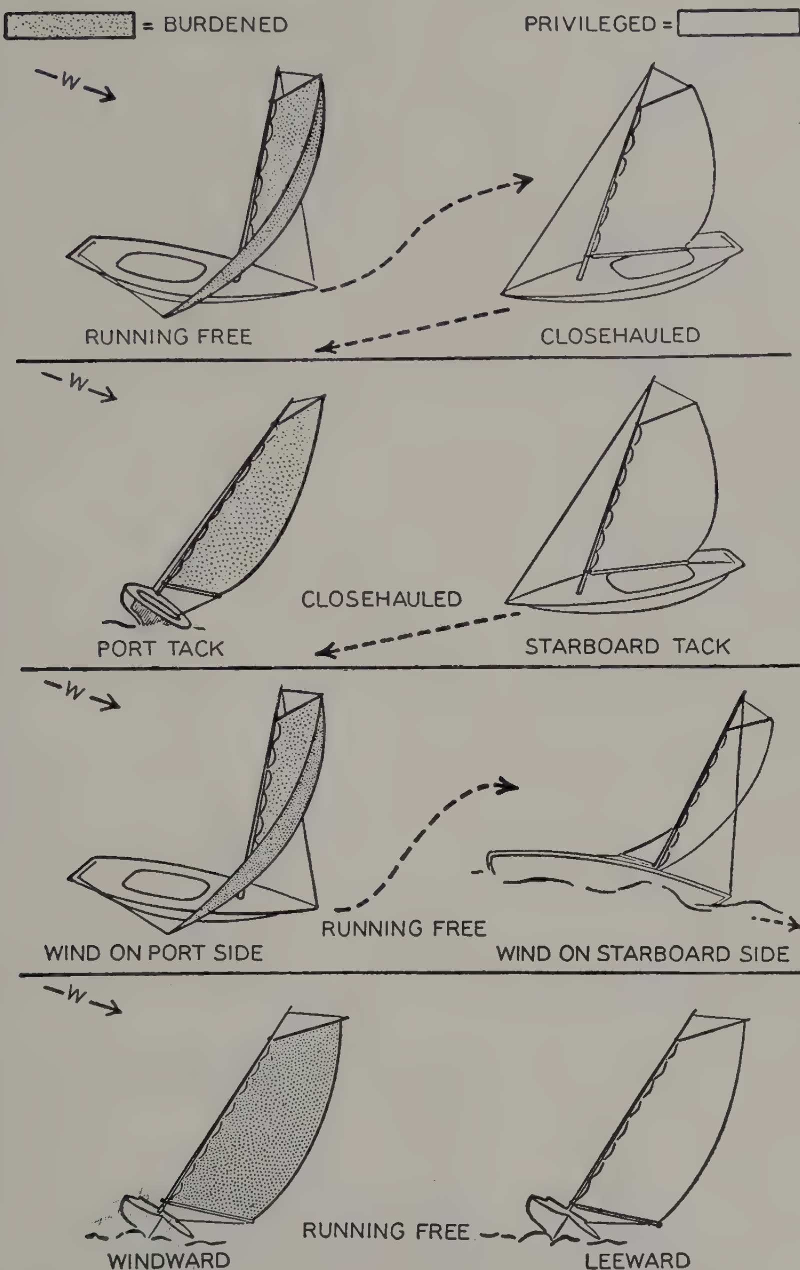


FIG. 20.1 SAIL VESSELS MEETING, INLAND WATERS

COMMENT: The present International Rule is new. Heretofore it was identical with the Inland Rule. The Rule is clear and simple, reflects modern sailing, and retains the prior principle of one vessel holding course and speed and the other giving way.

These Rules apply, differences notwithstanding, when risk of collision exists. The "burdened" vessel has one simple rule to observe—"keep out of the way of the other." The "privileged" vessel must hold her course. (ST. JOHN *v.* PAINE, 10 HOW (51 U.S.) 557.) The terms "burdened" and "privileged" depend on the course relative to the wind—the "tack" or whether the vessel is "running free" or "close-hauled." The "burdened" vessel is the one on the port tack, i.e., with the wind coming over the port side, or the one which is running free, or the one which is to windward.

The dividing line between "close-hauled" and "running free" has been the subject of a number of decisions, not always consistent. The weight of opinion is that a vessel heading within but not including two points of being close-hauled, i.e., two points "free," is close-hauled within the rules. She is "running free" on other headings.

No specific provision is made in the Inland Rules for a possible collision when both vessels are close-hauled on the same tack. The Overtaking Rule, Rule 24, would apply in such cases.

Sailing vessels cannot hamper power-driven vessels navigating a narrow channel. See Rule 20(b). Narrow channel usually includes all buoyed channels.

Sailing vessels are required to keep out of the way of vessels fishing with nets, lines, or trawls. See Rule 26 (Art. 26).

Steamers, i.e., power-driven vessels, must keep out of the way of sailing vessels. See Rule 20 (Art. 20).

There is an exception. Sailing vessels overtaking power-driven (steam) vessels must keep out of the way of the latter. See Rule 24 (Art. 24).

If a collision is imminent and it is apparent that the burdened sailing vessel cannot avoid a collision by her own acts, the privileged sailing vessel must take such seamanlike action as desirable to prevent the collision. (PIERRE CORNEILLE, 133 F 604.) A slight luffing is not a change of course. (THE MARMION, 1 ASP. 412.) If a vessel changes course into the wind by two points, it is a change of course under the Rules. (THE EARL WEMYS, 6 ASP. 407.) The change of course which is forced by a shoal or other well-known danger should be foreseen and expected by the burdened vessel. A vessel with the wind 1½ to 2½ points from dead astern was held sailing "with the wind aft." (TH' GOV. AMES, 187 F 40.)

INTERNATIONAL RULES

Rule 18 (Figs. 20.2, 20.3, and 20.4)

(a) When two power-driven vessels are meeting end on, or nearly end on, so as to involve risk of col-

INLAND RULES

Article 18 (Figs. 20.2, 20.3, and 20.4)

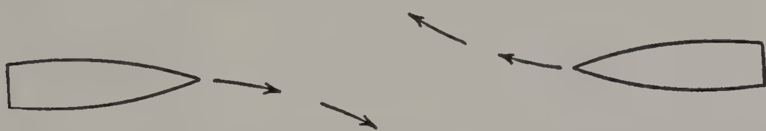
ART. 18. RULE I. *When steam vessels are approaching each other head and head, that is, end on, or nearly*

INTERNATIONAL RULES

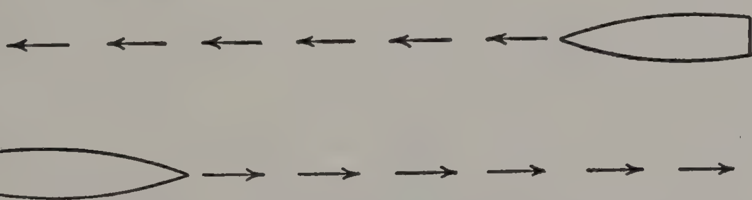
lision, each shall alter her course to starboard, so that each may pass on the port side of the other. This Rule only applies to cases where vessels are meeting end on, or nearly end on, in such a manner as to involve risk of collision, and does not apply to two vessels which must, if both keep on their respective courses, pass clear of each other. The only cases to which it does apply are when each of two vessels is end on, or nearly end on, to the other; in other words, to cases in which, by day, each vessel sees the masts of the other in a line, or nearly in a line, with her own; and by night, to cases in which

INLAND RULES

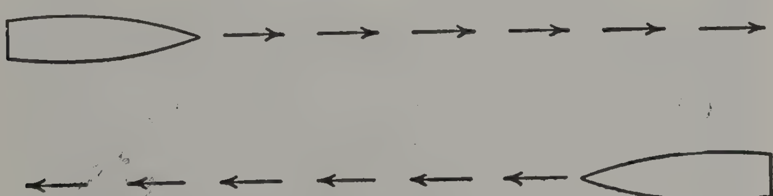
so, it shall be the duty of each to pass on the port side of the other; and either vessel shall give, as a signal of her intention, one short and distinct blast of her whistle, which the other vessel shall answer promptly by a similar blast of her whistle, and thereupon such vessels shall pass on the port side of each other. But if the courses of such vessels are so far on the starboard of each other as not to be considered as meeting head and head, either vessel shall immediately give two short and distinct blasts of her whistle, which the other vessel shall answer promptly by two similar



Here both ships change course to right and pass port side to port side, sounding one blast as course is changed. Same under International and Inland Rules.



Both ships may hold course and pass port side to port side. No sound signal under International Rules unless course is changed. One blast given by either and answered by the other under Inland Rules.



Both ships may hold course and pass starboard side to starboard side. No sound signal under International Rules unless course is changed. Two blasts given by either and answered by the other under Inland Rules.

FIG. 20.2 STEAM VESSELS MEETING HEAD-ON OR NEARLY HEAD-ON

INTERNATIONAL RULES

each vessel is in such a position as to see both the sidelights of the other. It does not apply, by day, to cases in which a vessel sees another ahead crossing her own course; or, by night, to cases where the red light of one vessel is opposed to the red light of the other or where the green light of one vessel is opposed to the green light of the other or where a red light without a green light or a green light without a red light is seen ahead, or where both green and red lights are seen anywhere but ahead.

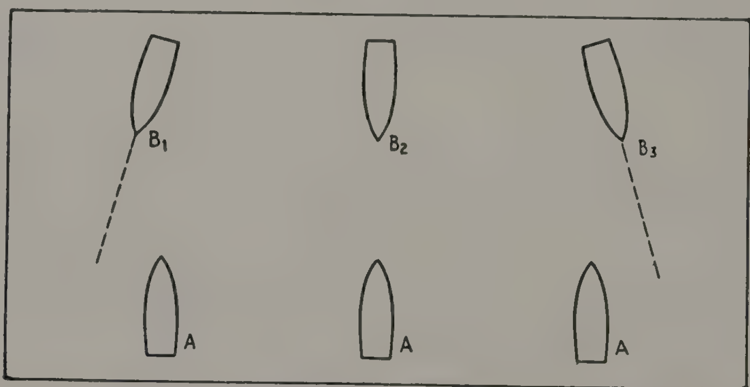
(b) For the purposes of this Rule and Rules 19 to 29 inclusive, except

INLAND RULES

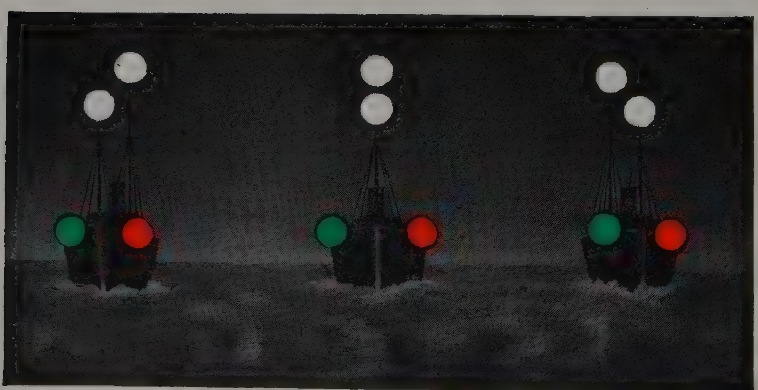
blasts of her whistle, and they shall pass on the starboard side of each other.

The foregoing only applies to cases where vessels are meeting end on, or nearly end on, in such a manner as to involve risk of collision; in other words, to cases in which, by day, each vessel sees the masts of the other in a line, or nearly in a line, with her own, and by night to cases in which each vessel is in such a position as to see both the sidelights of the other.

It does not apply by day to cases in which a vessel sees another ahead



Showing "B" as Seen by "A"



Range Lights

FIG. 20.3 STEAMERS MEETING. (Sidelights should not show across bow, but sometimes do so)

INTERNATIONAL RULES

Rule 20(c) and Rule 28, a seaplane on the water shall be deemed to be a vessel, and the expression "power-driven vessel" shall be construed accordingly.

See Rule 25(b).

INLAND RULES

crossing her own course, or by night to cases where the red light of one vessel is opposed to the red light of the other, or where the green light of one vessel is opposed to the green light of the other, or where a red light without a green light or a green light without a red light, is seen ahead, or where both green and red lights are seen anywhere but ahead.

RULE III. *If, when steam vessels are approaching each other, either vessel fails to understand the course or intention of the other, from any cause, the vessel so in doubt shall immediately signify the same by giving several short and rapid blasts, not less than four, of the steam whistle.*

RULE V. *Whenever a steam vessel is nearing a short bend or curve in the channel, where, from the height of the banks or other cause, a steam vessel approaching from the opposite direction can not be seen for a distance of half a mile, such steam vessel, when she shall have arrived within half a mile of such curve or bend, shall give a signal by one long blast of the steam whistle, which signal shall be answered by a similar blast given by any approaching steam vessel that may be within hearing. Should such signal be so answered by a steam vessel upon the*

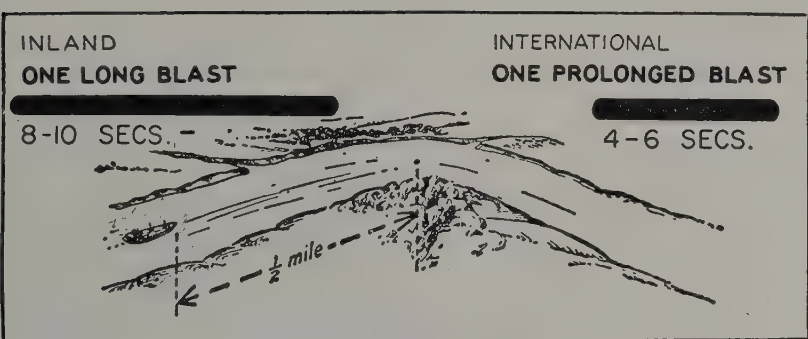


FIG. 20.4 STEAM VESSELS NEARING SHORT BEND

INTERNATIONAL RULES

INLAND RULES

farther side of such bend, then the usual signals for meeting and passing shall immediately be given and answered; but, if the first alarm signal of such vessel be not answered, she is to consider the channel clear and govern herself accordingly.

When steam vessels are moved from their docks or berths, and other boats are liable to pass from any direction toward them, they shall give the same signal as in the case of vessels meeting at a bend, but immediately after clearing the berths so as to be fully in sight they shall be governed by the steering and sailing rules.

RULE VIII. *When steam vessels are running in the same direction, and the vessel which is astern shall desire to pass on the right or starboard hand of the vessel ahead, she shall give one short blast of the steam whistle, as a signal of such desire, and if the vessel ahead answers with one blast, she shall direct her course to starboard; or if she shall desire to pass on the left or port side of the vessel ahead, she shall give two short blasts of the steam whistle as a signal of such desire, and if the vessel ahead answers with two blasts, shall direct her course to port; or if the vessel ahead does not think it safe for the vessel astern to attempt to pass at that point, she shall immediately signify the same by giving several short and rapid blasts of the steam whistle, not less than four, and under no circumstances shall the vessel astern attempt to pass the vessel ahead until such time as they have reached a point where it can be safely done, when said vessel ahead shall signify her willingness by blowing the proper signals. The vessel ahead shall in no case attempt to cross the bow or crowd upon the course of the passing vessel.*

INTERNATIONAL RULES

INLAND RULES

Rule IX. *The whistle signals provided in the rules under this article, for steam vessels meeting, passing, or overtaking, are never to be used except when steamers are in sight of each other, and the course and position of each can be determined in the daytime by a sight of the vessel itself, or by night by seeing its signal lights. In fog, mist, falling snow or heavy rainstorms, when vessels can not see each other, fog signals only must be given.*

INTERPRETIVE RULINGS — INLAND RULES

86.10–1 Bend signal and subsequent meeting situation.—Article 18, Rule V, and Article 18, Rule IX, of section 1, of the Act of June 7, 1897, as amended (33 U.S.C. 203), must be read together and followed after a bend signal is answered and the word "immediately" as used in Rule V shall be construed to require the exchange of sound signals for passing immediately upon sighting the other vessel.

PILOT RULES

80.03 Signals.—(a) The whistle signals provided in the rules in this part shall be sounded on an efficient whistle or siren sounded by steam or by some substitute for steam.

(1) A short blast of the whistle shall mean a blast of about 1 second's duration.

(2) A prolonged blast of the whistle shall mean a blast of from 4 to 6 seconds' duration.

(3) One short blast of the whistle signifies intention to direct course to own starboard, except when two steam vessels are approaching each other at right angles or obliquely, when it signifies intention of steam vessel which is to starboard of the other to hold course and speed.

(4) Two short blasts of the whistle signify intention to direct course to own port.

(5) Three short blasts of the whistle shall mean, "My engines are going at full speed astern."

(b) When vessels are in sight of one another a steam vessel under way whose engines are going at full speed astern shall indicate that fact by three short blasts on the whistle.

80.1 Danger signal.—If, when steam vessels are approaching each other, either vessel fails to understand the course or intention of the other, from any cause, the vessel so in doubt shall immediately signify the same by giving

several short and rapid blasts, not less than four, of the steam whistle, the danger signal.

80.2 Cross signals.—Steam vessels are forbidden to use what has become technically known among pilots as "cross signals," that is, answering one whistle with two, and answering two whistles with one.

80.3 Vessels passing each other.—(a) The signals for passing, by the blowing of the whistle, shall be given and answered by pilots, in compliance with the rules in this part, not only when meeting "head and head," or nearly so, but at all times when the steam vessels are in sight of each other, when passing or meeting at a distance within half a mile of each other, and whether passing to the starboard or port.

(b) The whistle signals provided in the rules in this part for steam vessels meeting, passing, or overtaking are never to be used except when steam vessels are in sight of each other, and the course and position of each can be determined in the daytime by a sight of the vessel itself, or by night by seeing its signal lights. In fog, mist, falling snow, or heavy rainstorms, when vessels cannot so see each other, fog signals only must be given.

80.4.—Same as Inland Rule, Art. 18, Rule I.

80.5.—Same as Inland Rule, Art. 18, Rule V.

80.6 Vessels running in same direction; overtaking vessel.—(a) When steam vessels are running in the same direction, and the vessel which is astern shall desire to pass on the right or starboard hand of the vessel ahead, she shall give one short blast of the steam whistle, as a signal of such desire, and if the vessel ahead answers with one blast, she shall direct her course to starboard; or if she shall desire to pass on the left or port side of the vessel ahead, she shall give two short blasts of the steam whistle as a signal of such desire, and if the vessel ahead answers with two blasts, shall direct her course to port; or if the vessel ahead does not think it safe for the vessel astern to attempt to pass at that point, she shall immediately signify the same by giving several short and rapid blasts of the steam whistle, not less than four, and under no circumstances shall the vessel astern attempt to pass the vessel ahead until such time as they have reached a point where it can be safely done, when said vessel ahead shall signify her willingness by blowing the proper signals. The vessel ahead shall in no case attempt to cross the bow or crowd upon the course of the passing vessel.

(b) Every vessel coming up with another vessel from any direction more than two points abaft her beam, that is, in such a position with reference to the vessel which she is overtaking that at night she would be unable to see either of that vessel's side lights, shall be deemed to be an overtaking vessel; and no subsequent alteration of the bearing between the two vessels shall make the overtaking vessel a crossing vessel within the meaning of the rules in this part, or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

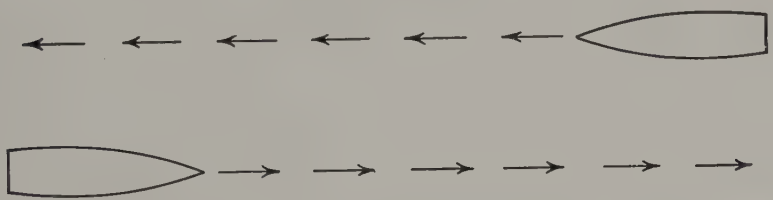
(c) As by day the overtaking vessel cannot always know with certainty whether she is forward of or abaft this direction from the other vessel she should, if in doubt, assume that she is an overtaking vessel and keep out of the way.

80.13(c) Diagrams.—The following diagrams are intended to illustrate the working of the system of colored lights and pilot rules.

FIRST SITUATION

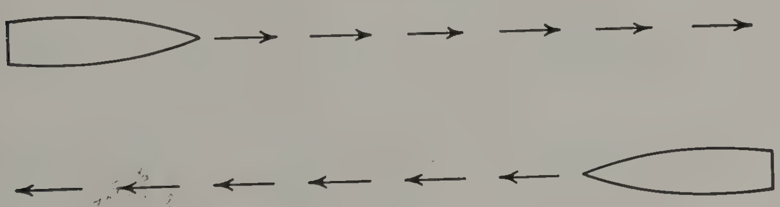
Here the two colored lights visible to each will indicate their direct approach "head and head" toward each other. In this situation it is a standing rule that both shall direct their courses to starboard and pass on the port side of each other, each having previously given one blast of the whistle.

SECOND SITUATION



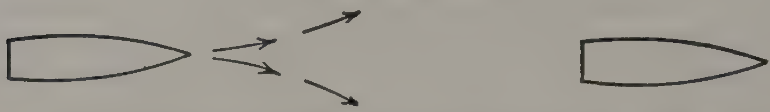
In this situation the red light only will be visible to each, the screens preventing the green lights from being seen. Both vessels are evidently passing to port of each other, which is rulable in this situation, each pilot having previously signified his intention by one blast of the whistle.

THIRD SITUATION



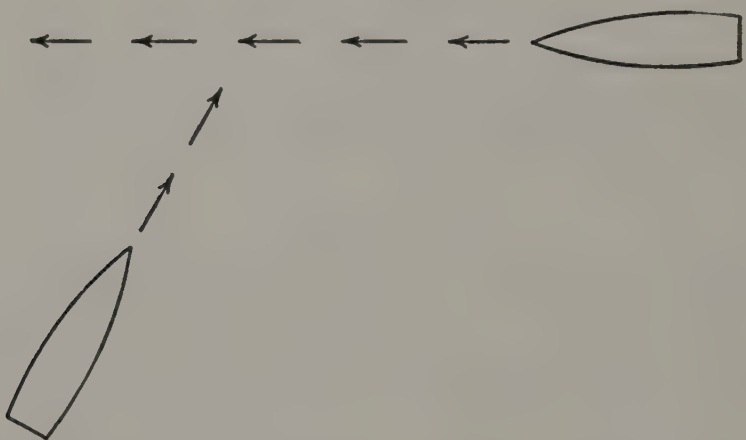
In this situation the green light only will be visible to each, the screens preventing the red light from being seen. They are therefore passing to starboard of each other, which is rulable in this situation, each pilot having previously signified his intention by two blasts of the whistle.

FOURTH SITUATION



In this situation one steam vessel is overtaking another steam vessel from some point within the angle of two points abaft the beam of the overtaken steam vessel. The overtaking steam vessel may pass on the starboard or port side of the steam vessel ahead after the necessary signals for passing have been given with assent of the overtaken steam vessel, as prescribed in § 80.6.

FIFTH SITUATION



In this situation two steam vessels are approaching each other at right angles or obliquely in such manner as to involve risk of collision, other than where one steam vessel is overtaking another. The steam vessel which has the other on her own port side shall hold course and speed, and the other shall keep clear by crossing astern of the steam vessel that is holding course and speed, or, if necessary to do so, shall slacken her speed, stop, or reverse.

COMMENT: The "end on" meeting case is dangerous because the rate of approach of the two vessels is the sum of the speeds of both vessels. The rate is the greatest of any meeting situation. The time is shorter. Thus the need for a timely exchange of signals and a strict compliance with the Rules are greatest.

The dividing line between "end on" and "crossing" cases has not been determined with exactness because the Rules contain the phrases "end on or nearly so" and "end on or nearly end on." Related court decisions have held approaching vessels to be meeting when on courses diverging by as much as one or two points, rendering a stricter interpretation in open waters than in restricted waters, such as rivers and narrow channels. The true test is that contained in the rules, i.e., ability to see both side lights, essentially ahead.

There have been many instances of confusion between meeting and crossing cases near the bend of a narrow channel or river. The Courts have ruled that the present courses, when the two vessels are on opposite sides of a bend and in sight, do not determine whether the case is crossing or meeting. It is decided by the probable future courses when they actually pass each other. "The question, therefore, always turns on the reasonable inference to be drawn as to a vessel's future course from her position at a particular moment, and this greatly depends on the nature of the locality where she is at the moment." (THE PEKIN, APP. CAS. 532.) ". . . has reference to the position of the two vessels when they will be meeting and about to pass each other, and not to their position when signals are given, if at that time they are on a temporary course from which they will depart before they will nearly approach each other." (THE WILLIAM CHISHOM, 153 F 704.)

The custom of passing starboard to starboard in Hell Gate on the flood tide has been upheld by the Courts. The question of whether the custom prevails throughout the whole period of the flood tide or only at its greatest strength has not been decided. The custom is not accepted on the ebb tide. Generally speaking, a custom must be "a reasonable custom of navigation arising from the peculiarities of this locality." (TRANSFER NO. 21, 248 F 459.)

A vessel ascending a river against a current should stop, if necessary, to facilitate a safe passing because she can stop and maintain her position more readily than a vessel descending with the current. (THE GALATEA, 92 U.S. 439.)

A meeting vessel should slow, stop, or reverse if she considers the situation dangerous or uncertain and if her passing signal has not been assented to or answered. (THE VICTORY, 168 U.S. 410.) Under the Inland Rules, the danger signal should be sounded. In International Waters, the corresponding danger signal cannot be used, unless the sounding vessel is to keep her course and speed under the Rules, etc. She may, however, show a flare-up or use a detonating or other efficient sound signal (see Rule 12) to attract attention to the situation.

The Inland and International Rules require a port-to-port passing if the two vessels meet end on or nearly so. If one vessel proposes a starboard-to-starboard passing in violation of the rules, she must secure the assent of the other vessel before proceeding (THE CITY OF TOKIO, 77 F 2d 315), and she assumes the risk of passing (THE TITAN, 49 F 479). The assenting vessel will not be held in fault unless she is negligent (THE MARACAIBO, 14 F 2d 686) or fails to do her part (THE RICHMOND, 124 F 993).

The Inland Rules require sound signals as an evidence of intention. International Rule 18 does not prescribe sound signals. They are described in Rule 28 and mean an actual change in course.

The International Rules do not mention a starboard-to-starboard passing. The Inland Rules provide for such passing under certain conditions.

Inland Rule V will be discussed under International Rule 25.

Inland Rule VIII will also be discussed under International Rule 24.

Inland Rule IX prescribes the conditions under which whistle signals are to be used. The steamers must be in sight. In fog, mist, falling snow, or heavy rainstorms, when vessels cannot see each other, fog signals only must be given.

One question regarding use of Inland Rule IX, in a bend situation, has been more-or-less settled by Interpretive Ruling 86.10-1.

The Courts have ruled that the alarm signal may be given in Inland Waters when the vessels are not in sight. (THE VIRGINIAN, 238 F 156.)

The second sentence of Article 18, Rule 1, Inland Rules, which begins "But if the courses . . . ," should be moved to the end of Rule 1, Article 18, in order that the third sentence, which begins "The foregoing only applies . . . ," shall refer to "end on" meetings and not to an "end on" meeting or a starboard-to-starboard meeting.

INTERNATIONAL RULES

Rule 19 (Figs. 20.5 and 20.6)

When two power-driven vessels are crossing, so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way of the other.

INLAND RULES

Article 19 (Figs. 20.5 and 20.6)

Same as International Rule except "steam" is used in place of "power-driven."

PILOT RULES

80.7 Vessels approaching each other at right angles or obliquely.—(a) When two steam vessels are approaching each other at right angles or obliquely so as to involve risk of collision, other than when one steam vessel is overtaking another, the steam vessel which has the other on her own port side shall hold her course and speed; and the steam vessel which has the other on her own starboard side shall keep out of the way of the other by directing her course to starboard so as to cross the stern of the other steam vessel, or, if necessary to do so, slacken her speed or stop or reverse.

(b) If from any cause the conditions covered by this situation are such as to prevent immediate compliance with each other's signals, the misunderstanding or objection shall be at once made apparent by blowing the danger signal, and both steam vessels shall be stopped and backed if necessary, until signals for passing with safety are made and understood.

COMMENT: This rule applies when there is risk of collision. If a risk of collision exists, the subsequent changes of course or bearing do not change the original responsibility of "the vessel which has the other on her own starboard side" to keep clear. The burdened and privileged vessels are not changed until all danger of collision has passed.

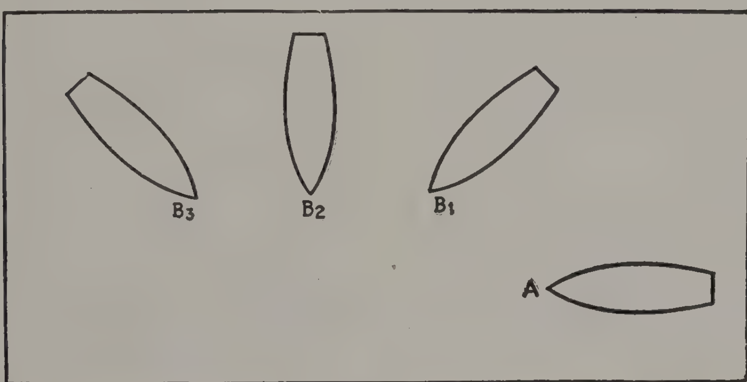
Risk of collision exists "from the time the necessity for precaution begins. . . ." (MR. JUSTICE CLIFFORD, 1859.)

The Steering and Sailing Rules apply when a single vessel approaches a formation of warships. If the single vessel wishes to show good sea manners

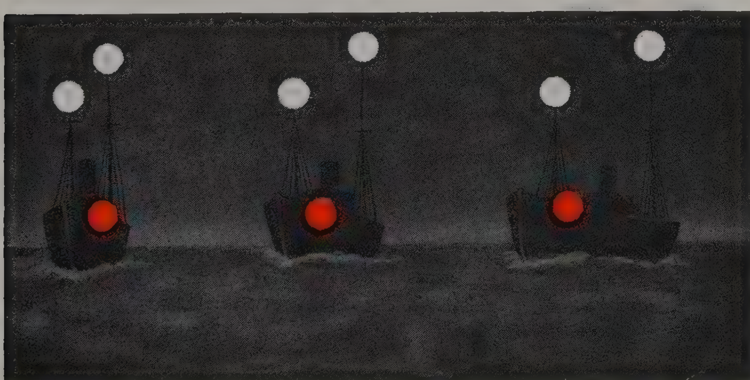
and good sense, she should change course, if necessary, to avoid the formation before the risk of collision exists.

Ferryboats are entitled to a reasonable opportunity to enter and leave their slips. Other vessels should not pass close to the slip. Rule 19 does not apply when ferryboats are maneuvering to enter or leave their slips. Rule (Article) 27 applies. After the ferryboats have "come to" a course, on leaving or while they are still on one course, straight or curved, when approaching the slip, Rule 19 does apply. The same instructions apply to a vessel getting under way from an anchorage or when about to anchor.

The exchange of a two-blast signal in a crossing case in Inland Waters does not, of itself, shift the responsibility of the burdened vessel to keep clear and of the privileged vessel to hold course and speed. Courts are divided as to the effect of such an exchange of signals, except for one point: agreement creates a situation of "special circumstances." In the absence of strict obedience to the



Crossing: "A" Sights "B" to Starboard



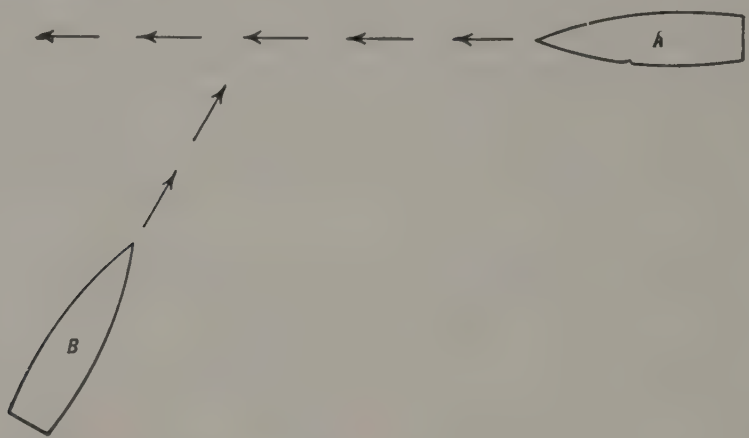
INTERNATIONAL AND INLAND

Range Lights

FIG. 20.5 STEAMERS WITH RANGE LIGHTS CROSSING FROM STARBOARD

rules, both vessels must be prepared to take action to avert collision. In International Waters, where one and two blast signals indicate rudder action, no signal is given, unless course is changed.

COURT DECISIONS: The failure of a privileged vessel to answer a crossing signal in Inland Waters, which violates the rule, is not an assent but is the same as a dissent. The burdened vessel should obey the rule, then. (THE ELDORADO, 89 F 1015.)



A holds course and speed.
No sound signal under International Rules.
One blast under Inland Rules.
B crosses astern of A, slowing, stopping, backing, or changing course as necessary.
Under International Rules B gives no sound signal unless she changes course or backs.
Under Inland Rules B sounds one blast to signify her intention of crossing astern of A whether she changes course or not.

FIG. 20.6 STEAM VESSELS IN CROSSING SITUATION

If the other vessel in Inland Waters ignores or does not hear the initiating vessel's blast or blasts, it is proper to repeat the original signal. (VICTORY, 168 U.S. 410.)

If the privileged vessel fails to answer the burdened vessel's two blasts, the latter vessel should not proceed to cross ahead under the impression that she has the initiative. (THE CYGNUS, 142 F 85.) "The right of way is not created by blowing a whistle. The law directs how a vessel shall pass." (THE HERMES, 21 F 2d 314.)

Comment has already been made on two vessels approaching a bend who seem, for the moment, to be crossing but who will be meeting when they pass. (THE PEKIN, APP. CAS. 532.)

When a vessel is meeting two others in Inland Waters, she should exchange whistles with the first encountered. After that exchange has occurred, she should then exchange signals with the second vessel encountered. (THE CITY OF TOKIO, 9 F Supp 715.)

The assenting vessel may be found in fault if she assents to a proposal which is dangerous. (THE ARTHUR M. PALMER, 115 F 417.)

When signals have been exchanged, each vessel must promptly act in accordance with the signal. (THE GALILEO, 24 F 386.)

Pilots exchange cross signals occasionally. These signals are forbidden in Inland Waters, see Pilot Rule par. 80.2 above. They are not mentioned in the International or Inland Rules.

"A course (for the privileged vessel) is not necessarily a straight course and may be a turning or a swinging one." (THE CRANFORD, 27 F 2d 710.) The giving way (burdened) vessel is not expected to foresee that the privileged vessel's course is not straight if such fact is not evident. (THE JOHN ENGLIS, 9 LL. L. REP. 400.)

INTERNATIONAL RULES

Rule 20

(a) When a power-driven vessel and a sailing vessel are proceeding in such directions as to involve risk of collision, except as provided for in Rules 24 and 26, the power-driven vessel shall keep out of the way of the sailing vessel.

(b) This Rule shall not give to a sailing vessel the right to hamper, in a narrow channel, the safe passage of a power-driven vessel which can navigate only inside such channel.

(c) A seaplane on the water shall, in general, keep well clear of all vessels and avoid impeding their navigation. In circumstances, however, where risk of collision exists, she shall comply with these Rules.

INLAND RULES

Article 20

ART. 20. *When a steam vessel and a sailing vessel are proceeding in such directions as to involve risk of collision, the steam vessel shall keep out of the way of the sailing vessel.*

Not in Inland Rules.

Not in Inland Rules.

PILOT RULES

80.8.—Same as Inland Article 20.

COMMENT: This rule applies to all cases where a power-driven (steam) vessel meets a sailing vessel except when the sailing vessel overtakes a steam vessel or meets one not under command or fishing with nets or lines or trawls. When a sailing vessel and a steam or power-driven vessel meet or cross, normally the sailing vessel should hold her course. A shoal, rock, or the bank may force the sailing vessel to tack. No fault can be ascribed to a sailing vessel for changing course or tacking if she does so when she must and no more than she needs to do. The sailing vessel should hold her course until there is an immediate danger of collision and then take the action which will prevent collision under Rule 27.

The second paragraph of Rule 20, International Rules, is new. It is the result of small sailing vessels blocking channels needlessly by taking advantage of their general right of way over power-driven vessels. The purpose of the Rule is to require small sailing vessels to keep to the right of a channel, or to clear a channel, when a large steamer is navigating in tight quarters. Action under the Rule should be taken early, with full realization that the other vessel sometimes cannot slow or stop easily.

The third paragraph of Rule 20, International Rules, dates from the 1948 International Rules. There are four distinct points which should be made:

(a) A seaplane on the water is a power-driven vessel—see Rule 18(b).
(b) A seaplane on the water shall in general keep well clear of all vessels before risk of collision exists.
(c) However, after risk of collision exists, the seaplane and the other vessel shall obey the Rules.
(d) Masters of other vessels should realize that seaplanes cannot reverse their engines and that they do not maneuver readily in strong winds and choppy seas.

INTERNATIONAL RULES

Rule 21

Where by any of these Rules one of two vessels is to keep out of the way, the other shall keep her course and speed. When, from any cause, the latter vessel finds herself so close that collision cannot be avoided by the action of the giving-way vessel alone, she also shall take such action as will best aid to avert collision (see Rules 27 and 29).

INLAND RULES

Article 21

ART. 21. *Where, by any of these rules, one of the two vessels is to keep out of the way, the other shall keep her course and speed.*

[*See articles 27 and 29.*]

COMMENT: This Rule requires the privileged vessel to keep the course and speed which may reasonably be expected under the circumstances so that the burdened vessel may know what changes of course or speed or both she must make "to keep out of the way." However, the privileged vessel must take such action as will best aid to avert collision when immediate collision cannot be avoided by the action of the burdened vessel alone. This point is a matter of judgment. The holding on vessel may be forced, eventually, to assume the responsibility of deciding when to depart from this Rule and to comply with Rule 27.

COURT DECISIONS: The Rule which requires the privileged vessel "to keep her course and speed" does not mean the actual compass course and speed at the time when signals are sounded but "in my judgment 'course and speed' in Article 21 mean course and speed in following the nautical maneuver in which, to the knowledge of the other vessel, the vessel is at the time engaged.

. . ." (THE ROANOKE, PROB. DIV. 231.) The privileged vessel may be showing a flag requesting a pilot or she may be about to pick up or drop one. A shoal, bank, ledge, or other danger well known to the burdened vessel may force the privileged vessel to change her course and speed. The burdened vessel should still keep clear. The privileged vessel should not change her course or speed until it is necessary or more than necessary. (THE GEORGE DUMOIS, 153 F 833.) The Rule does not apply when vessels are not in sight in a fog. (THE D. S. GREGORY, D.C. N.Y. 1874.)

INTERNATIONAL RULES

Rule 22

Every vessel which is directed by these Rules to keep out of the way of another vessel shall, so far as possible, take positive early action to comply with this obligation, and shall, if the circumstances of the case admit, avoid crossing ahead of the other.

INLAND RULES

Article 22

Every vessel which is directed by these rules to keep out of the way of another vessel shall, if the circumstances of the case admit, avoid crossing ahead of the other.

PILOT RULES

80.9.—Same as Inland Rule 22 except the Pilot Rule is applied to steam vessels only.

COMMENT: The International and Inland Rules apply to all vessels, but the Pilot Rule applies to steam vessels only. This limitation does not affect the validity of the Pilot Rule.

COURT DECISIONS: The Courts have frequently held that this rule should not be violated for convenience sake. (THE E. A. PACKER, 140 U.S. 360.) "Exceptions to the general rules of navigation are admitted with reluctance on the part of the Courts, and only when the adherence to such rules must almost necessarily result in a collision. . . ." (THE ALBERT DUOIS, 177 U.S. 240.)

In some ports there is a custom among pilots and vessels customarily plying these waters to sound two blasts and cross ahead. "If there is a custom which permits Sound steamers to claim exemption from the operation of this Article . . . when approaching ferries in the East River on the ebb tide, such custom is opposed to law and cannot prevail." (THE PEQUOT, 30 F 839.)

INTERNATIONAL RULES

Rule 23

Every power-driven vessel which is directed by these Rules to keep out of the way of another vessel shall, on approaching her, if necessary, slacken her speed or stop or reverse.

INLAND RULES

Article 23

Same as International Rules except "steam" replaces "power-driven."

PILOT RULES

Not in Pilot Rules

COMMENT: The Rule does not prescribe the maneuvers which the master of the burdened ship shall make to keep out of the way. It merely states that the burdened vessel shall slacken her speed, stop, or reverse if it is necessary. The burdened vessel may change course, slow down, stop, or reverse, or any combination of these actions. There is only one course of action which is denied the burdened vessel, namely, she shall avoid crossing ahead if the circumstances of the case admit.

COURT DECISION: "The burdened vessel is to keep out of the way. How it shall do so, is not prescribed. . . . If she makes the attempt [to cross the bows of the privileged vessel] and thereby brings about a collision, she is in fault for not keeping out of the way of the privileged vessel." (THE GEORGE S. SHULTZ, 84 F 508.)

INTERNATIONAL RULES

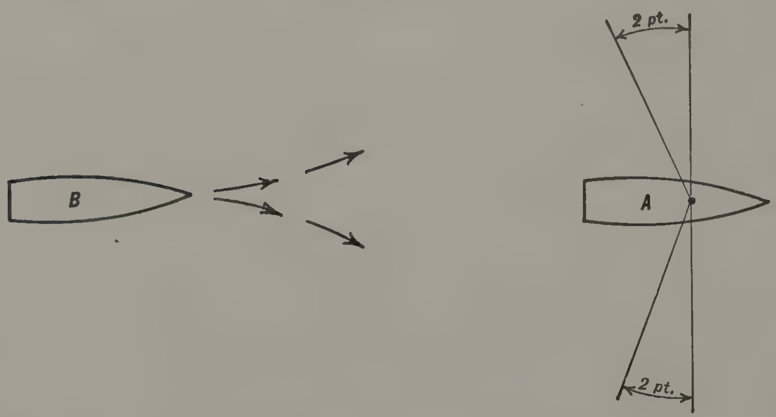
Rule 24 (Fig. 20.7)

(a) Notwithstanding anything contained in these Rules, every vessel overtaking any other shall keep out of the way of the overtaken vessel.

INLAND RULES

Article 24 (Fig. 20.7)

ART. 24. *Notwithstanding anything contained in these rules every vessel, overtaking any other, shall keep out of the way of the overtaken vessel.*



B is overtaking vessel if in arc 2 points abaft either beam of A. If in doubt B assumes she is overtaking. B must keep clear of A until finally past and clear.

International Rules: No sound signals are given unless either changes course or backs when appropriate signals are given.

Inland Rules: B gives one short blast if she wishes to pass on starboard hand and two short blasts if she wishes to pass on her port hand.

The same signal repeated by A gives permission for B to pass as requested.

FIG. 20.7 POWER-DRIVEN OR STEAM VESSELS IN OVERTAKING SITUATIONS

INTERNATIONAL RULES

(b) Every vessel coming up with another vessel from any direction more than $22\frac{1}{2}$ degrees (2 points) abaft her beam, i.e., in such a position, with reference to the vessel which she is overtaking, that at night she would be unable to see either of that vessel's sidelights, shall be deemed to be an overtaking vessel; and no subsequent alteration of the bearing between the two vessels shall make the overtaking vessel a crossing vessel within the meaning of these Rules, or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

(c) If the overtaking vessel cannot determine with certainty whether she is forward of or abaft this direction from the other vessel, she shall assume that she is an overtaking vessel and keep out of the way.

INLAND RULES

Every vessel coming up with another vessel from any direction more than two points abaft her beam, that is, in such a position, with reference to the vessel which she is overtaking that at night she would be unable to see either of that vessel's side lights, shall be deemed to be an overtaking vessel; and no subsequent alteration of the bearing between the two vessels shall make the overtaking vessel a crossing vessel within the meaning of these rules, or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

As by day the overtaking vessel cannot always know with certainty whether she is forward of or abaft this direction from the other vessels she should, if in doubt, assume that she is an overtaking vessel and keep out of the way.

Article 18

RULE VIII. *When steam vessels are running in the same direction, and the vessel which is astern shall desire to pass on the right or starboard hand of the vessel ahead, she shall give one short blast of the steam whistle, as a signal of such desire, and if the vessel ahead answers with one blast, she shall direct her course to starboard; or if she shall desire to pass on the left or port side of the vessel ahead, she shall give two short blasts of the steam whistle as a signal of such desire, and if the vessel ahead answers with two blasts, shall direct her course to port; or if the vessel ahead does not think it safe for the vessel astern to attempt to pass at that point, she shall immediately signify the same by giving several short and rapid blasts of the steam whistle, not less than four, and under no circumstances shall the vessel astern attempt to pass the vessel ahead until such time as they have reached a*

INTERNATIONAL RULES

INLAND RULES

point where it can be safely done, when said vessel ahead shall signify her willingness by blowing the proper signals. The vessel ahead shall in no case attempt to cross the bow or crowd upon the course of the passing vessel.

PILOT RULES

80.6 Vessels running in same direction; overtaking vessel.—(a) When steam vessels are running in the same direction, and the vessel which is astern shall desire to pass on the right or starboard hand of the vessel ahead, she shall give one short blast of the steam whistle, as a signal of such desire, and if the vessel ahead answers with one blast, she shall direct her course to starboard; or if she shall desire to pass on the left or port side of the vessel ahead, she shall give two short blasts of the steam whistle as a signal of such desire, and if the vessel ahead answers with two blasts, shall direct her course to port; or if the vessel ahead does not think it safe for the vessel astern to attempt to pass at that point, she shall immediately signify the same by giving several short and rapid blasts of the steam whistle, not less than four, and under no circumstances shall the vessel astern attempt to pass the vessel ahead until such time as they have reached a point where it can be safely done, when said vessel ahead shall signify her willingness by blowing the proper signals. The vessel ahead shall in no case attempt to cross the bow or crowd upon the course of the passing vessel.

(b) Every vessel coming up with another vessel from any direction more than two points abaft her beam, that is, in such a position with reference to the vessel which she is overtaking that at night she would be unable to see either of that vessel's side lights, shall be deemed to be an overtaking vessel; and no subsequent alteration of the bearing between the two vessels shall make the overtaking vessel a crossing vessel within the meaning of the rules in this part, or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

(c) As by day the overtaking vessel cannot always know with certainty whether she is forward of or abaft this direction from the other vessel she should, if in doubt, assume that she is an overtaking vessel and keep out of the way.

COMMENT: Neither the International nor the Inland Rules require the overtaking vessel to pass the overtaken vessel on a particular side. The Pilot Rule deals with steam vessels only. All three Rules allow the overtaking vessel to pass on either hand, provided, in Inland Waters, the proper signal has been sounded by the overtaking vessel and assented to by the other vessel. Good seamanship on confined waters suggests that the passing shall be to port if safe

and practicable because the overtaken vessel is required by Article 25, Inland Rules, "to keep to that side of the fairway or mid-channel which lies on the starboard side of such vessel." The overtaken vessel may be forced to move to starboard if she meets another vessel, end on. Such a move to starboard might be awkward if not dangerous to the overtaking vessel trying to pass to starboard. The overtaken vessel must hold her course after the passing signal has been sounded. She can make such changes as might reasonably be expected under the conditions, i.e., change to avoid a vessel or danger.

The overtaking vessel must continue to keep out of the way until well past and clear where a change in her course or speed will not affect the other vessel.

COURT DECISIONS: The overtaken vessel should not assent to the passing unless it is safe to do so. The failure to sound the dissenting (danger) signal, in Inland Waters, when it is dangerous to pass, has been ruled a fault of the overtaken vessel. (THE JARANGER, C.C.A. Md, 1931.)

An overtaking vessel, in Inland Waters, cannot be denied her right to pass by the overtaken vessel which refuses to answer a passing signal. However, the overtaking vessel should not attempt to pass "unless in a clearly safe place for passing. . . ." She must not "attempt to pass in a place of doubtful safety without a signal of assent." (THE MESABA, 111 F 215.)

A great number of collisions in overtaking cases have been caused by suction. The overtaking vessel must allow ample room to pass the overtaken vessel. The overtaking vessel is liable for a collision caused by her failure to do so and by the sheering of the overtaken vessel due to suction or current. (THE FRED JANSEN, 49 F 254.)

The overtaking vessel must allow for changes of course of the overtaken vessel due to following the channel or to avoiding a third vessel. (THE HACKENSACK, 32 F 800.) (MORGAN'S LOUISIANA R.R. CO., 9 F 2d 174.)

INTERNATIONAL RULES

Rule 25 (See Fig. 20.4)

(a) In a narrow channel every power-driven vessel when proceeding along the course of the channel shall, when it is safe and practicable, keep to that side of the fairway or mid-channel which lies on the starboard side of such vessel.

(b) Whenever a power-driven vessel is nearing a bend in a channel where a vessel approaching from the other direction cannot be seen, such power-driven vessel, when she shall have arrived within one-half (½) mile of the bend, shall give a signal by one prolonged blast on her whistle, which signal shall be an-

INLAND RULES

Article 25 (See Fig. 20.4)

ART. 25. *In narrow channels every steam vessel shall, when it is safe and practicable, keep to that side of the fairway or mid-channel which lies on the starboard side of such vessel.*

Article 18

RULE V. *Whenever a steam vessel is nearing a short bend or curve in the channel, where, from the height of the banks or other cause, a steam vessel approaching from the opposite direction can not be seen for a distance of half a mile, such steam vessel, when she shall have arrived within half a mile of such*

INTERNATIONAL RULES

swered by a similar blast given by any approaching power-driven vessel that may be within hearing around the bend. Regardless of whether an approaching vessel on the farther side of the bend is heard, such bend shall be rounded with alertness and caution.

(c) In a narrow channel a power-driven vessel of less than 65 feet in length shall not hamper the safe passage of a vessel which can navigate only inside such channel.

INLAND RULES

curve or bend, shall give a signal by one long blast of the steam whistle, which signal shall be answered by a similar blast given by any approaching steam vessel that may be within hearing. Should such signal be so answered by a steam vessel upon the farther side of such bend, then the usual signals for meeting and passing shall immediately be given and answered; but, if the first alarm signal of such vessel be not answered, she is to consider the channel clear and govern herself accordingly.

When steam vessels are moved from their docks or berths, and other boats are liable to pass from any direction toward them, they shall give the same signal as in the case of vessels meeting at a bend, but immediately after clearing the berths so as to be fully in sight they shall be governed by the steering and sailing rules.

NOTE: A **long** blast is one of 8 to 10 seconds.

RULE IX. *The whistle signals provided in the rules under this article, for steam vessels meeting, passing, or overtaking, are never to be used except when steamers are in sight of each other, and the course and position of each can be determined in the daytime by a sight of the vessel itself, or by night by seeing its signal lights. In fog, mist, falling snow or heavy rainstorms, when vessels can not see each other, fog signals only must be given.*

INTERPRETIVE RULINGS—INLAND RULES

86.10–1 Bend signal and subsequent meeting situation.

Article 18, Rule V, and Article 18, Rule IX, of section 1, of the Act of June 7, 1897, as amended (33 U.S.C. 203), must be read together and followed after a bend signal is answered and the word "immediately" as used in Rule V shall be construed to require the exchange of sound signals for passing immediately upon sighting the other vessel.

PILOT RULES

80.10.—Same as Inland Article 25.

Comment: The International Rule has three conditions, namely, the channel must be narrow, the vessel must be "proceeding along the course of the channel," and "it is safe and practicable." The first condition exempts wide bodies of navigable water, such as certain parts of Chesapeake Bay. The second has in mind the fact that vessels move across certain channels. The last is that obstructions may make navigation along one side of a channel unsafe.

The Inland Rules mention two limitations only, "narrow" and "safe and practicable."

Both Rules are not mandatory unless it is safe and practicable to obey them. The Rules apply to bodies of water which are narrow, carry two lanes of traffic, and are limited by banks or shoals or buoys or anchorage grounds. Certain channels which are much used, although surrounded by navigable water for some vessels, have been ruled "narrow."

The International and Inland Rules about power-driven (steam) vessels approaching a bend in a channel are fundamentally the same, except that the International Rules emphasize the need for alertness and caution in rounding the bend whether an answering blast is heard or not. The Inland Rules state the vessel is to consider the channel clear and govern herself accordingly if no answering blast is heard. If both power-driven (steam) vessels are within one-half mile of the bend and can see each other, no warning blasts are required.

After the vessels are in sight, the usual signals for meeting and passing should be given. The Inland Rules make definite provision for these signals. The situation is covered by Rules 18 and 28 in the International Rules.

The International Rules do not provide specifically for power-driven vessels moving from their docks or berths. The Inland Rules require such vessels to sound one long blast. This "slip whistle" or "change of status whistle" is prescribed so that an approaching vessel is warned that another vessel is about to emerge into the channel from the slip. Passing vessels should not proceed unnecessarily close to the end of the piers. The slip whistle should be continued or repeated until the emerging vessel is visible to other vessels. (THE DALZELLA, 109 F 2d 101.) A vessel which is backing out of a slip and must swing to proceed along a course is governed by Rule 27 until she reaches that course. (THE SERVIA, 149 U.S. 144.) If the vessel leaving encounters a vessel at close quarters, Rule 27 applies. If a vessel has emerged from a slip, bow first, and is on a recognized course, straight or curved, and if there is time to apply the crossing rule, it governs. (THE GULF OF SUEZ, PROB. DIV. 318.)

Court Decisions: "Channels within the Rule are bodies of water navigated up and down in opposite directions, and that therefore harbor waters, with

piers on each side where the necessities of commerce require navigation in every conceivable direction, up and down, across, and up and down between piers on the same side, cannot be considered narrow channels." (THE NO. 4, 161 F 847.)

The Courts have ruled that certain channels are narrow and others are not. (COMMONWEALTH *v.* DOMINION LINE, 258 F 707.)

"Rule 25 is not to be construed as prohibiting vessels from crossing such a channel at any convenient angle whenever the exigencies of their own navigation make it necessary or desirable for them to proceed from one to the other side of the channel; but when no exigency exists, they should keep to the proper side of the channel." (THE LA BRETAGNE, 179 F 286.)

The custom of violating this rule (narrow channels) to take advantage of counter currents "does not alter the fact that any vessel that goes up in that way [on the left side] violates the law and takes the risk, and, if there is a collision, is presumably at fault." (THE TRANSFER NO. 10, 137 F 666.)

"A vessel which approaches a narrow channel when another vessel is coming out, should keep to her own side of the channel." (THE ATLANTIC TRANSPORT CO., 15 F 2d 544.)

"Each of these vessels was entitled to presume that the other would act lawfully; would keep to her own side. . . ." (THE VICTORY, 168 U.S. 410.)

"When a vessel, located at rest in a slip, has cast off and is about to start out of the slip bow first or stern first, it is her duty to blow a single long blast, usually spoken of as a 'slip whistle.' " (THE JOHN ARBUCKLE, 185 F 240.)

INTERNATIONAL RULES

Rule 26

All vessels not engaged in fishing, except vessels to which the provisions of Rule 4 apply, shall, when under way, keep out of the way of vessels engaged in fishing. This Rule shall not give to any vessel engaged in fishing the right of obstructing a fairway used by vessels other than fishing vessels.

INLAND RULES

Article 26

ART. 26. *Sailing vessels under way shall keep out of the way of sailing vessels or boats fishing with nets, lines, or trawls. This rule shall not give to any vessel or boat engaged in fishing the right of obstructing a fairway used by vessels other than fishing vessels or boats.*

PILOT RULES

None

COMMENT: The International Rule applies to all vessels and the Inland Rule to sailing vessels only.

The Rule is based on the principle that vessels able to maneuver should keep out of the way of vessels whose movements are restricted or who cannot maneuver.

A fairway has been ruled as water on which vessels of commerce habitually move.

INTERNATIONAL RULES

Rule 27

In obeying and construing these Rules due regard shall be had to all dangers of navigation and collision, and to any special circumstances, including the limitations of the craft involved, which may render a departure from the above Rules necessary in order to avoid immediate danger.

INLAND RULES

Article 27

ART. 27. *In obeying and construing these rules due regard shall be had to all dangers of navigation and collision, and to any special circumstances which may render a departure from the above rules necessary in order to avoid immediate danger.*

PILOT RULES

80.11 Departure from rules.—In obeying and construing the rules in this part due regard shall be had to all dangers of navigation and collision, and to any special circumstances which may render a departure from said rules necessary in order to avoid immediate danger.

COMMENT: Note that the two Rules are the same except for the phrase "including the limitations of the craft involved" which has been inserted in the International Rules. It is apparent that the known limitations in the maneuverability of a seaplane on the water has been one of the reasons for adding this phrase. It applies, however, to many other cases.

The Courts have decided that this Rule (27) does not take precedence over the other steering and sailing rules. They should be obeyed in almost all situations, where risk of collision exists and there is time and room to apply them. However, the Rules were enacted to prevent collisions. The law cannot foresee the many different situations that could occur. Article 27 is binding, therefore, for the unusual, out-of-the-ordinary case where obedience to the other rules would probably cause a collision. The Courts have ruled that the following situations are governed by Rule 27:

1. A steamer backs out of a slip or a dock and is turning preparatory to proceeding farther.
2. A ferryboat is maneuvering to enter or to leave her slip.
3. A vessel has just weighed anchor and is "casting" to proceed.
4. A pilot is about to board or leave a vessel.

The common case is where two vessels are about to collide and the burdened vessel is not able to avoid a collision by her own actions.

A vessel cannot disregard the other rules and apply this General Prudential Rule when and as it suits her convenience.

COURT DECISIONS: "I am of the opinion that departure from Article 18 (and

compliance with Rule 27) is justified when such departure is the one chance still left of avoiding danger which otherwise is inevitable." (THE BENARES, 5 ASP. M.C.)

"The duty is to avoid collision by observing the rules, primarily, by departing from them, if necessary, to avoid danger." (THE HERCULES, 51 F 452.)

"A vessel, coming out of her slip and maneuvering to get on her course or one maneuvering to get into her slip, is not navigating on any course, and the steering and sailing rules do not apply." (THE WILLIAM A. JAMISON, 241 F 950.)

21

Passing Signals, Etc., Rules (Articles) 28–32

INTERNATIONAL RULES

PART E.—SOUND SIGNALS FOR VESSELS IN SIGHT OF ONE ANOTHER

Rule 28

(a) When vessels are in sight of one another, a power-driven vessel under way, in taking any course authorised or required by these Rules, shall indicate that course by the following signals on her whistle, namely:

One short blast to mean "I am altering my course to starboard."

Two short blasts to mean "I am altering my course to port."

Three short blasts to mean "My engines are going astern."

(b) Whenever a power-driven vessel which, under these Rules, is to keep her course and speed, is in sight of another vessel and is in doubt whether sufficient action is being taken by the other vessel to avert collision, she may indicate such doubt by giving at least five short and rapid blasts on the whistle. The giving of such a signal shall not relieve a vessel of her obligations under Rules 27 and 29 or any other Rule, or of her duty to indicate any action taken under these Rules by giving the appropriate sound signals laid down in this Rule.

(c) Any whistle signal mentioned in this Rule may be further indicated by a visual signal consisting of a

INLAND RULES

Article 28

ART. 28. *When vessels are in sight of one another a steam vessel under way whose engines are going at full speed astern shall indicate that fact by three short blasts on the whistle.*

See Article 18, Rules I, III, VIII, and IX.

Not in Inland Rules.

INTERNATIONAL RULES	INLAND RULES
white light visible all round the horizon at a distance of at least 5 miles, and so devised that it will operate simultaneously and in conjunction with the whistle-sounding mechanism and remain lighted and visible during the same period as the sound signal.	
(d) Nothing in these Rules shall interfere with the operation of any special rules made by the Government of any nation with respect to the use of additional whistle signals between ships of war or vessels sailing under convoy.	*Not in Inland Rules.*

PILOT RULES

80.03 Signals.—(a) The whistle signals provided in the rules in this part shall be sounded on an efficient whistle or siren sounded by steam or by some substitute for steam.

(1) A short blast of the whistle shall mean a blast of about one second's duration.

(2) A prolonged blast of the whistle shall mean a blast of from 4 to 6 seconds' duration.

(3) One short blast of the whistle signifies intention to direct course to own starboard, except when two steam vessels are approaching each other at right angles or obliquely, when it signifies intention of steam vessel which is to starboard of the other to hold course and speed.

(4) Two short blasts of the whistle signify intention to direct course to own port.

(5) Three short blasts of the whistle shall mean, "My engines are going at full speed astern."

(b) When vessels are in sight of one another a steam vessel under way whose engines are going at full speed astern shall indicate that fact by three short blasts on the whistle.

80.1 Danger signal.—If, when steam vessels are approaching each other, either vessel fails to understand the course or intention of the other, from any cause, the vessel so in doubt shall immediately signify the same by giving several short and rapid blasts, not less than four, of the steam whistle, the danger signal.

80.2 Cross signals.—Steam vessels are forbidden to use what has become technically known among pilots as "cross signals," that is, answering one whistle with two, and answering two whistles with one.

80.26 Passing signals. (Floating Plant)—(a) Vessels intending to pass dredges or other types of floating plant working in navigable channels, when

within a reasonable distance therefrom and not in any case over a mile, shall indicate such intention by one long blast of the whistle, and shall be directed to the proper side for passage by the sounding, by the dredge or other floating plant, of the signal prescribed in the local pilot rules for vessels under way and approaching each other from opposite directions, which shall be answered in the usual manner by the approaching vessel. If the channel is not clear, the floating plant shall sound the alarm or danger signal and the approaching vessel shall slow down or stop and await further signal from the plant.

(b) When the pipe line from a dredge crosses the channel in such a way that an approaching vessel cannot pass safely around the pipe line or dredge, there shall be sounded immediately from the dredge the alarm or danger signal and the approaching vessel shall slow down or stop and await further signal from the dredge. The pipe line shall then be opened and the channel cleared as soon as practicable; when the channel is clear for passage the dredge shall so indicate by sounding the usual passing signal as prescribed in paragraph (a) of this section. The approaching vessel shall answer with a corresponding signal and pass promptly.

(c) When any pipe line or swinging dredge shall have given an approaching vessel or tow the signal that the channel is clear, the dredge shall straighten out within the cut for the passage of the vessel or tow.

80.27 Speed of vessels passing floating plant working in channels.—Vessels, with or without tows, passing floating plant working in channels, shall reduce their speed sufficiently to insure the safety of both the plant and themselves, and when passing within 200 feet of the plant their speed shall not exceed five miles per hour. While passing over lines of the plant, propelling machinery shall be stopped.

80.28 Light-draft vessels passing floating plant.—Vessels whose draft permits shall keep outside of the buoys marking the ends of mooring lines of floating plant working in channels.

NOTE: The term "floating plant" as used in Sections 80.26 to 80.31a, inclusive, includes dredges, derrick boats, snag boats, drill boats, pile drivers, maneuver boats, hydraulic graders, survey boats, working barges, and mat sinking plant.

80.35 Rule prohibiting unnecessary sounding of the whistle.—Unnecessary sounding of the whistle is prohibited within any harbor limits of the United States. Whenever any licensed officer in charge of any vessel shall authorize or permit such unnecessary whistling, such officer may be proceeded against in accordance with the provisions of R.S. 4450, as amended, looking to a revocation or suspension of his license.

COMMENT: The basic difference between the International Rules and the Inland and Pilot Rules, as far as one-and-two blast whistle signals are concerned, is that the International Rules mean an actual change of course is being made and the Inland Rules signify an intention to pass a certain way,

which may or may not include change of course. The Courts have ruled that, when a whistle signal, in Inland Waters, has been sounded and assented to, the two vessels must carry out promptly the maneuver proposed and accepted. "The steamer's delay in acting on her own signal was plainly at her own risk." (GALILEO, 24 F 386.)

Whistle signals are provided for power-driven (steam) vessels when vessels are in sight. The Rules require fog signals to be sounded in a fog when the vessels are not in sight. An exception is a Court ruling that permits the sounding of a danger signal in a fog in Inland Waters.

Comment has already been made that signals must be given in plenty of time for the other vessel to understand the maneuver and to act upon it.

The difference between the conditions under which a danger signal may be sounded in the International and Inland Waters should be noted. The International Rules lay down three conditions:

1. A power-driven vessel is to keep her course and speed. This eliminates meeting vessels, the burdened vessel in crossing cases, the overtaking vessel, either vessel when Rule 27 applies, i.e., when collision is imminent, any vessel navigating a bend in a channel.
2. When vessels are in sight of each other. This prevents the use of the danger signal in a fog before the vessels sight each other.
3. To indicate a doubt whether sufficient action is being taken by the other vessel to avert collision.

The Inland Rules, on the other hand, permit the danger signal to be blown when:

(a) Either vessel fails to understand the course or intention of the other from any cause.
(b) In a fog before vessels are in sight.

Rule 28(c) is new and limited to International Waters. It establishes an optional white light which can be used as a "visual whistle." When used the light has to be completely synchronized with the whistle so as to reflect accurately the sound signal given. The limitation to International Waters notwithstanding, it can be expected to be seen in Inland Waters, on sea-going vessels, as a matter of convenience, and practical necessities to ensure proper synchronization.

Rule 28(d) International Rules permits the use of additional whistle signals between ships-of-war or vessels sailing under convoy. The Rule does not sanction the failure to use the whistle in the fog or in meeting, crossing, or overtaking cases. The Rule merely legalizes an old custom in the U.S. Fleet of using the whistle to signal a simple maneuver in a formation of ships. Pilot Rule 80.35 does not prohibit such signalling, although care must be taken that such signals do not confuse merchant vessels.

COURT DECISION: The Courts have ruled that vessels backing at less than full speed or making sternway should sound three blasts. (THE SICILIAN PRINCE, 144 F 951.)

INTERNATIONAL RULES

PART F.—MISCELLANEOUS

Rule 29

Nothing in these Rules shall exonerate any vessel, or the owner, master or crew thereof, from the consequences of any neglect to carry lights or signals, or of any neglect to keep a proper lookout, or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

INLAND RULES

Article 29

Same as International Rules.

COMMENT: This Rule and number 27 are the ones which cover unusual situations and cases. They are sometimes called the "Articles of Good Seamanship." Collision cannot be avoided in every case by following a written set of rules. These two Rules require the master of a vessel to apply his knowledge of seamanship and to take appropriate action when adherence to the Rules would probably cause a collision.

A lookout must: (a) be trained, (b) have no other duties, (c) be stationed where he can see and hear best, (d) have good communication with the officer in charge of the vessel, and (e) be vigilant. Additional lookouts are necessary in restricted visibility. A station in the bow is considered by the Courts to be more desirable and useful than one in the foretop. A lookout aft is necessary when backing out of a slip. A lookout is also required at anchor. These are the proper lookouts and stations as handed down by the Courts.

The speed of a vessel is not prescribed by the Rules except:

1. In a fog (it must be moderate).
2. For a "privileged vessel" (she must keep her speed):
3. For a "burdened vessel" (she must slacken her speed or stop or reverse, if necessary).
4. Vessels passing near floating plants, working in a channel. (Passing vessels shall reduce their speed.)

The Courts, however, have ruled that vessels shall reduce speed when:

(a) In confined, busy waters.
(b) Approaching a bend when vessels on the other side cannot be seen.
(c) Passing close to another vessel which cuts off the view beyond.
(d) Whistle signals are not understood or agreed to.

(e) In doubt as to the intention or course of another vessel.
(f) Passing close to the ends of docks or near to ferry slips.
(g) Necessary "to do no injury to others that care and prudence may avoid." This includes reducing speed in harbors to prevent damage to other vessels, their mooring lines, or equipment.
(h) Cross signals are sounded.

Many of the requirements of good seamanship have already been discussed:

(a) Know the Rules and obey them.
(b) Know the differences between the International and Inland Rules.
(c) Carry the proper running lights.
(d) Make certain that these lights are burning brightly.
(e) If required to change course, make a noticeable change and in good time so that the other vessel will notice the change and have time to make her proper maneuver safely.
(f) Don't expect seaplanes on the water to maneuver as easily as a small boat.
(g) Give tugs with tows plenty of sea room before risk of collision exists.
(h) Observe and allow for the effect of the wind, tide, current, and suction on the tow.
(i) Pass dredges or vessels working under the water slowly, without leaving a dangerous wake.
(j) Give sailing vessels extra sea room. They have been known to luff or come about.
(k) Observe vessels narrowly approaching or leaving a pilot vessel.
(l) Don't run over fishing stakes or buoys.
(m) Navigate with care on well-known fishing grounds.
(n) Keep well clear of fishing vessels.
(o) Proceed at a "moderate" speed in a fog. You can make up the time later. The vessel and the lives of your men are your responsibility.
(p) Stop when a fog whistle is heard forward of your beam. Reduce speed still more, when the whistle sounds close.
(q) Reduce speed in restricted waters so that your wake will not damage other craft.
(r) Anchor in an authorized anchorage.
(s) Anchor outside of narrow channels.
(t) Take extra precautions if forced to anchor in a narrow channel.
(u) Anchor clear of lines of traffic.
(v) Select an anchorage which allows room to swing without fouling other vessels already anchored.
(w) Show good sea manners.

COURT DECISIONS: The Supreme Court in THE ARIADNE, in 1871, ruled that "For an officer to leave his vessel entirely without a lookout, especially when another vessel is known to be in the vicinity, is culpable negligence."

"A competent lookout, stationed upon the quarter of the vessel affording the best opportunity to see at a distance those meeting her, is indispensable to safe navigation and the neglect is chargeable as a fault in the navigation." (THE CATHARINE, 58 U.S. 170.)

"He [the lookout] has only one duty, that which its name implies, to keep a look-out." (THE ARLYN, 1930 A.M.C. 532.)

INTERNATIONAL RULES

Rule 30

Nothing in these Rules shall interfere with the operation of a special rule duly made by local authority relative to the navigation of any harbour, river, lake, or inland water, including a reserved seaplane area.

INLAND RULES

Article 30

ART. 30. *The exhibition of any light on board of a vessel of war of the United States or a Coast Guard cutter may be suspended whenever, in the opinion of the Secretary of the Navy, the commander in chief of a squadron, or the commander of a vessel acting singly, the special character of the service may require it.*

COMMENT: The Inland Rules, Great Lakes, and Western Rivers Rules, enacted by Congress, and the Pilot Rules, established by the Commandant of the Coast Guard, are "special rules" duly made by local authority. There are others. (See earlier chapters.)

Article 30, Inland Rules, has been discussed in earlier chapters.

INTERNATIONAL RULES

Rule 31

(a) When a vessel or seaplane on the water is in distress and requires assistance from other vessels or from the shore, the following shall be the signals to be used or displayed by her, either together or separately, namely:

(i) A gun or other explosive signal fired at intervals of about a minute.

(ii) A continuous sounding with any fog-signal apparatus.

(iii) Rockets or shells, throwing red stars fired one at a time at short intervals.

(iv) A signal made by radiotelegraphy or by any other signalling method consisting of the group ···———··· in the Morse Code.

INLAND RULES

Article 31

ART. 31. *When a vessel is in distress and requires assistance from other vessels or from the shore the following shall be the signal to be used or displayed by her, either together or separately, namely:*

In the daytime—

A continuous sounding with any fog-signal apparatus, or firing a gun.

At night—

First. Flames on the vessel as from a burning tar barrel, oil barrel, and so forth.

Second. A continuous sounding with any fog-signal appartus, or firing a gun.

INTERNATIONAL RULES

(v) A signal sent by radiotelephony consisting of the spoken word "Mayday."

(vi) The International Code Signal of distress indicated by N.C.

(vii) A signal consisting of a square flag having above or below it a ball or anything resembling a ball.

(viii) Flames on the vessel (as from a burning tar barrel, oil barrel, &c.).

(ix) A rocket parachute flare or a hand flare showing a red light.

(x) A smoke signal giving off a volume of orange-colored smoke.

(xi) Slowly and repeatedly raising and lowering arms outstretched to each side.

NOTE: *Vessels in distress may use the radiotelegraph alarm signal or the radiotelephone alarm signal to secure attention to distress calls and messages. The radiotelegraph alarm signal, which is designed to actuate the radiotelegraph auto alarms of vessels so fitted, consists of a series of twelve dashes, sent in 1 minute, the duration of each dash being 4 seconds, and the duration of the interval between 2 consecutive dashes being 1 second. The radiotelephone alarm signal consists of 2 tones transmitted alternately over periods of from 30 seconds to 1 minute.*

(b) The use of any of the foregoing signals, except for the purpose of indicating that a vessel or seaplane is in distress, and the use of any signals which may be confused with any of the above signals, is prohibited.

INLAND RULES

Article 32

ART. 32. *All orders to helmsmen shall be given as follows:*

"Right Rudder" to mean "Direct the vessel's head to starboard."

"Left Rudder" to mean "Direct the vessel's head to port."

Authority of Master vs. Pilot

The Supreme Court in the OREGON, 158 U.S. 186, ruled: ". . . while the pilot doubtless supersedes the master for the time being in the command and navigation of the ship, and his orders must be obeyed in all matters connected with her navigation, the master is not wholly absolved from his duties while the pilot is on board, and may advise with him, and even displace him in case he is intoxicated or manifestly incompetent."

Not all pilots are competent.

Captains of naval vessels are reminded that a pilot is merely an adviser to the commanding officer. This officer is still responsible for the navigation and handling of the ship, except in the Panama Canal where the pilot assigned to a naval vessel has control of the navigation and movement of the vessel.

There have been cases where the pilot in the Panama Canal has relinquished control over a naval vessel to its usual commanding officer in moments of stress.

There are special orders about the responsibility of a commanding officer when the naval vessel under his command is moved, with or without her own power, in a naval station or in or out of a dry dock.

Part IV

OCEANOGRAPHY AND WEATHER

22

Oceanography

The seaman who must cope with the elements of nature during a lifetime on the sea should understand the fundamental processes of the oceans especially as they affect shiphandling and the safety of ship, cargo, and personnel at sea. Our knowledge of the oceans is still incomplete, but great progress is being made in the science of oceanography.

Every applied field of endeavor is based on the theoretical work of some fundamental scientific discipline. For those who go to sea, navigation is based on the science of astronomy. Marine engineering derives its practical applications from the laws of physics, as does cargo handling. Sanitation and health at sea can trace their origins back through medicine to chemistry, biology, but especially microbiology and pharmacology. Similarly seamanship, the safe handling of a ship on or under the surface of the sea, is founded on the science of oceanography.

From the mariner's point of view the object of knowing oceanography is to influence the forces of the oceans or at least to use them to the best advantage. The ability to locate currents, predict storms, avoid fog, or prevent marine life from eroding the underwater portions of the hull makes the mariner's life at sea safer and more comfortable. It also enables him to perform his other basic tasks more effectively, such tasks as transporting passengers, hauling cargo, launching aircraft, hunting enemy submarines, catching fish, or just sailing around for fun and pleasure.

Safety at sea is, of course, vital to mariners but one sometimes loses sight of the number of ships lost at sea. Insurance records show that 217,000 ships have sunk or run aground during the last 100 years and that approximately 2000 ships of all types are lost each year. Oceanography cannot reduce losses due to fire or collision but it has materially reduced losses due to storms, ice, inadequate charts, and oceanic phenomena affecting the safe navigation of ships.

The magnitude of our shipping effort should also be understood in order to see why oceanography is important to mariners. In 1966 the active, ocean-going U.S. merchant fleet consisted of 1012 ships of 1000 gross tons or over with a total tonnage of over 13 million tons. It included 27 passenger cargo ships, 733 freighters, and 252 tankers. The industry provides employment for 200,000 people and contributes $5 billion annually to the U.S. economy.

History

Although men have been travelling on the water since the first cave man sailed down a river on a tree trunk, the systematic study of the oceans is barely 120 years old. In the 1840's Matthew Fontaine Maury, a lieutenant in the U.S. Navy, analyzed the logs of countless sailing ships which enabled him to develop wind-current charts, thereby greatly reducing the sailing time between ports. This work by the father of oceanography gave American clipper ships an advantage that contributed materially to the prosperity and economic health of America before the Civil War.

The next important step in understanding oceanic processes came from the British Challenger expedition (1872–1876). HMS Challenger was commissioned by the British Admiralty to make a worldwide study of the physical, chemical, and biological conditions in the oceans. The leader of the expedition, Sir John Murray, published the scientific results of the voyage in 50 volumes which for years gave scientists much valuable food for thought.

Table 22.1 Unsolved Oceanographic Problems of Interest to Mariners

1. What specific frequencies of the electromagnetic spectrum will detect submarines at longest ranges?
2. How are sound waves affected by the absorbing and reflecting characteristics of the ocean bottom?
3. How can oceanography contribute to improving the anti-submarine warfare capability of the U.S.?
4. How are storms generated at sea?
5. How can oceanographic conditions be predicted?
6. How can marine fouling organisms be controlled?
7. What effect will atomic waste disposal have on marine life?
8. How many fish are there in the oceans and how can they best be harvested?
9. How can oceanographic data be processed by high-speed electronic computers to develop "models" of typical ocean areas?
10. How do oceanographic conditions affect marine life?
11. How did the oceans originate?
12. How can pure water and other mineral compounds be economically extracted from sea water?
13. How are atomic and other wastes dispersed through the oceans?
14. How do some marine organisms used for food by man tolerate and store poisons at concentrations harmful or lethal to man?
15. Why is the layer of unconsolidated sediments in the deep sea so thin (average 1000 ft thick)?
16. Why are there no sea fossils older than 100 million years?
17. What is the cause of the sudden increase in radium content in the oceans about 200,000 years ago?
18. Why does the deep sea floor off the west coast of North America have such regular magnetic conditions?
19. What are the enzyme systems that operate in the oceanic regions of high pressure and perpetual low temperature?
20. How do microscopic plants and animals (plankton), apparently helpless in the face of water movement, maintain themselves so regularly in their own specific regions?
21. How are internal waves generated and what is their role in tidal friction?
22. What worldwide changes in sea level have occurred in the past?
23. What are the mechanisms of sediment erosion, transportation, and deposition on the shelf and in the surf zone?
24. What are the effects on climate of stirring up deep ocean waters?
25. How can we account for the radically different biological evolutionary rates that we find in the sea?

As a result of the monumental work of the Challenger expedition, the major maritime nations of the world became interested in the oceans as an untapped source of scientific knowledge. At first the effort was very modest. Major countries would have a few small oceanographic ships while smaller countries restricted themselves to one or two very small ships capable of limited coastal or estuarine oceanographic work.

World Wars I and II both pointed out the need for understanding the oceans as a three dimensional naval operating environment, thereby giving greater impetus to oceanography. The biggest push came, however, after the launching of Sputnik in October 1957. Space flight studies have generated a worldwide desire to study the unknown scientific frontiers of human knowledge. The oceans, as the last unmapped frontier on our planet, came in for their share of scientific support. In fact the effort has been almost equal (in terms of interest by scientists as well as by the general public) to that of space flight.

Table 22.2.* Importance of Physical Properties of Water

Property	Comparison with Other Substances	Importance
Heat capacity	Highest of all solids and liquids except liquid NH_3.	Prevents extreme ranges in temp. Heat transfer by water is very large. Tends to maintain uniform body temperature in marine animals.
Latent heat of fusion	Highest except for NH_3.	Acts as thermostat at freezing point due to absorption or release of latent heat.
Latent heat of evaporation	Highest of all substances.	Heat and water transfer between sea and atmosphere influences weather.
Thermal expansion	Maximum density for pure water occurs above freezing point.	Helps control temperature distribution and vertical circulation.
Surface tension	Highest of all liquids.	Cell physiology. Controls formation and behavior of water droplets for air-sea interaction.
Dissolving power	In general, dissolves more substances and in greater quantity than any other liquid.	Over 40 elements found in solution in sea water.
Dielectric constant	Pure water has highest of all liquids.	Affects behavior of inorganic dissolved substances due to high dissociation.
Electrolytic dissociation	Very small.	A neutral substance but contains both H^+ and OH^- ions.
Transparency	Poor in comparison with air.	Absorption of radiant energy is large in infra red and ultra violet. Penetration of visible portion of energy spectrum is important for biological processes. Absorption of electromagnetic energy makes submarine detection very difficult.
Conduction of heat	Highest of all liquids.	Cell physiology.

* Adapted from Sverdrup, Johnson, and Fleming, *The Oceans* (Englewood Cliffs: Prentice-Hall, 1942), p. 48.

Table 22.1 lists some of the problems that oceanographers are working on, the solution of which will be of great assistance to mariners.

Table 22.2 gives the importance of some of the physical properties of water. It is the study of these properties and their distribution and changes throughout the oceans that is the basis of physical and chemical oceanography.

The Marine Environment

The sea is divided arbitrarily into two primary types of environment: BENTHIC is concerned with the ocean floor and PELAGIC refers to the water mass. As can be seen from Fig. 22.1, the benthic division is composed

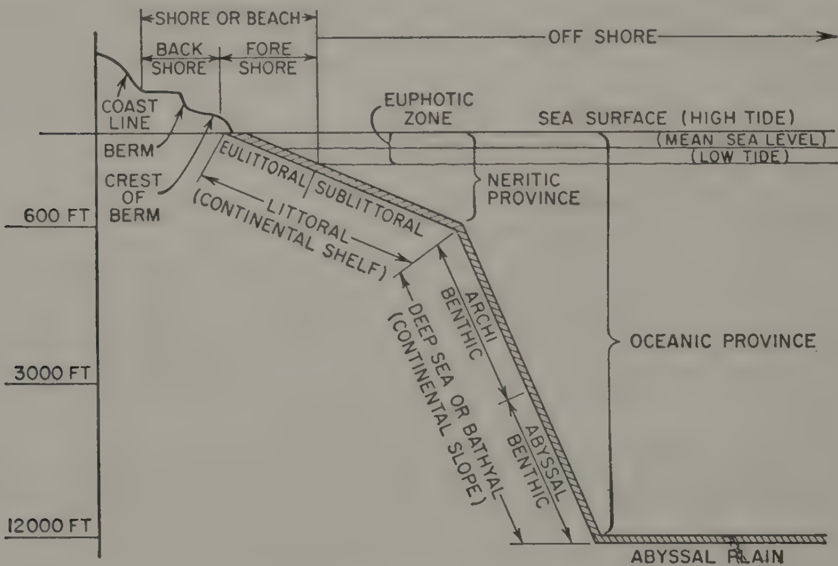


FIG. 22.1 THE MARINE ENVIRONMENT

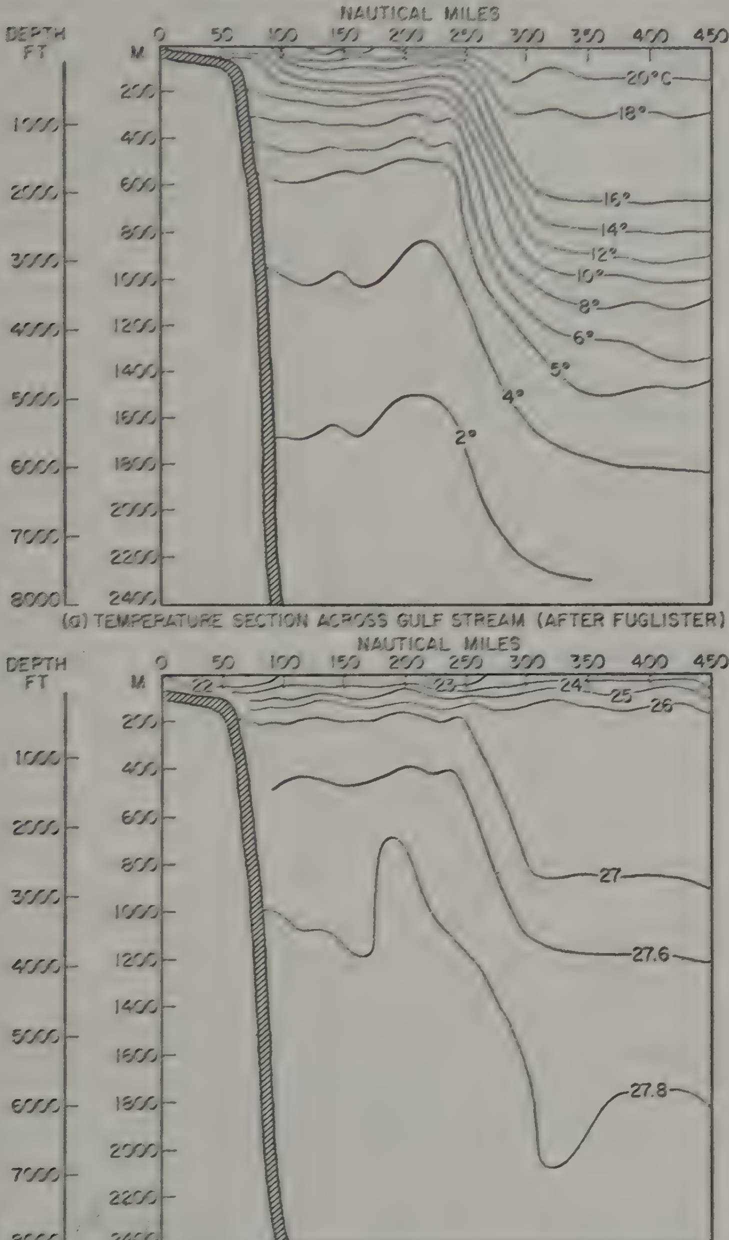
of the littoral and deep set categories which in turn are composed of eulittoral (or intertidal) and sublittoral zones. The pelagic division is divided into the neritic province and oceanic province. Classification is sometimes made by combining two overlapping regions, for example: pelagic-abyssal.

The borders of any particular zone are not clearly defined because different oceanographic disciplines have varying requirements. Uniform requirements cannot be drawn to fit all possible conditions. For biological purposes a zone might end where attached plants cease to grow; for geological purposes this same zone would have different boundaries because of changes in types of sediments; for physical oceanographers the zone might end at the point where surface wave action ceased to have an effect.

The boundary limits shown in Figure 22.1 and tabulated in Table 22.3

TABLE 22.3. APPROXIMATE BOUNDARIES AND CHARACTERISTICS OF VARIOUS MARINE ENVIRONMENTS

	Benthic					
	Littoral				Pelagic	
	Eulittoral	Sublittoral	Archi-Benthic	Abyssal Benthic	Neritic	Oceanic
Depth in meters	0–50m some authors confine it to tidal range	50m–200m	200m–1000m	greater than 1000m	0–200m	greater than 200m
Distance from coast in miles	usually less than 10 miles	1–650 miles av 50 miles	out to 650 miles	greater than 10 miles	out to 650 mi	greater than 10 miles
Flora	attached plants	none	none	none	floating plants	floating plants in limited amounts
Fauna	abundant fauna. Primarily sessile	sessile	detritus eating carnivores	detritus eaters	abundant fauna all types	all types but in limited amounts
Light	well lighted	varying light	dark	dark	dark	dark
Temp	Not applicable for ocean bottom				varies with season from −1° to 30°C, 30°C to 86°F	5° to −1°C 41° to 30°F
Salinity	Not applicable for ocean bottom				reduced salinity in areas where there is large inflow of fresh water	depends on depth and water masses



(a) TEMPERATURE SECTION ACROSS GULF STREAM (AFTER FUGLISTER)

(b) DENSITY (σ_t) SECTION ACROSS GULF STREAM (AFTER FUGLISTER)

FIG. 22.2 TYPICAL TEMPERATURE AND DENSITY (σ_t) SECTIONS ACROSS GULF STREAM. From Von Arx, *Introduction to Physical Oceanography* (Reading, Mass.: Addison-Wesley, 1962), pp. 317, 318

island arcs such as the Japanese, Philippine, and Mariana Islands. In addition, the Pacific is much bigger and deeper than the Atlantic.

One of the most far-reaching results of the Challenger expedition was the discovery that the oceans throughout the world are composed of the same ions of salts and other minerals, in the same relative percentage regardless of the absolute ionic concentration of the dissolved material. By measuring the percentage of any particular ion in a sample the percentage of any other can be found based on its relative proportion to the total measured solids.

The oceanographer measures a number of parameters but the basic ones with which he works are temperature, salinity, and depth. From these three values he is able to map ocean currents, trace water masses over wide ocean areas at various depths, and in general make the numerous computations needed to determine the laws that govern oceanic processes.

Figure 22.2 shows plots of temperature vs. depth and density in an area of the Gulf Stream.

These vertical profiles show the striking correlation that exists with temperature, density (Σ_t), and currents. The Gulf Stream, in these sections, is between 200 and 250 miles from the coast. In both cases the iso-lines for temperature and density make a marked downward swing to indicate the edge of the Gulf Stream. Horizontal ocean currents can be located by graphical sections of temperature and/or density and can be computed by the method of dynamic heights based on temperature-salinity measurements which give density values. This graphical presentation (Fig. 22.2) gives a vivid illustration of how sound also is distorted in the presence of water currents, temperature changes, or density changes.

Oceanographic Instruments

Although the oceans are homogeneous in gross terms there are minor variations on the order of one or two parts per million. It is the oceanographer's job to measure these variations precisely but to do this he must use tools and techniques which are extremely accurate. Table 22.4 lists the parameters measured at sea, the accuracy of the measurements, and the instrument usually employed. It is not possible in a single chapter to describe in detail all of the instruments carried on an oceanographic ship. Emphasis will therefore be given to the major instruments, many of which are also carried on non-oceanographic ships.

22.1 Echo sounders are instruments installed near the ship's keel to measure the depth of water by determining the time taken for sound waves to travel from the ship to the bottom and return. The equipment is designed to produce the sound, receive and amplify the echo, measure the time interval between the emitted signal and its return echo, and convert the time interval into units of depth measurement, such as feet, fathoms, or meters.

TABLE 22.4. PARAMETERS RECORDED AT SEA *

Parameter	Accuracy	Instrument
For annotating data:		
Latitude and longitude	±0.1 naut mile	Inertial navigation with precise electronic system
Time	±0.01 second	Chronometer and radio time signals
Relatively constant parameters:		
Depth	±5 fathoms	Echo sounder
Gravity	±2 milligals	Shipboard gravimeter
Magnetics	±0.01 gamma	Towed magnetometer
Strata profiles	—	Seismic techniques with explosives
Cores	—	Kullenberg corer
Variable water parameters:		
Sea temp vs depth	±0.01°C	Reversing thermometer
Salinity vs depth	±0.01°/00	Nansen bottle and chemical analysis
Sound velocity vs depth	±0.1 ft/sec	Greenspan-Tschiegg sound velocimeter
Oxygen content	1 part/million	Chemical analysis
Ambient noise	1 cycle/sec	Hydrophones
Heat flow at bottom	±0.05 microcalorie/cm²/second	Maxwell heat probe
Tides	±0.1 ft	Coast and geodetic survey tide gauges
Currents	±0.1 knot	Roberts, Savonius, and/or Swallow buoys
Variable air-sea interface parameters:		
Surface air temp.	±0.1°/F	Thermometer
Humidity	±5%	Hygrometer and wet-dry bulb thermometers
Surface water temp.	±0.1°F	Injection thermometer or bucket thermometer
Sea swell	±1 ft	Wave recorder
Barometric pressure	±2 millibars	Mercury barometer
Wind speed	±3 knots	Anemometer
Wind direction	±5 degrees	Anemometer
Wave height	±1 ft	Wave recorder
Incident radiation	±5%	Radiometer
Reflected radiation	±5%	Radiometer

* Based on Table D, p. 262, Ocean Sciences, U.S. Naval Institute, 1964.

Modern echo sounders, by using narrow beams with high frequency (12 kc), are capable of recording a continuous graphic profile of the deeper bottom while the ship is moving through the water at very fast speeds. Electronic mechanical detachments, known as Precision Depth Recorders (PDR), are available for operation with the echo sounder to give an expanded profile of the bottom. The PDR has a paper width of 24 inches corresponding to 400 fathoms.

The device reveals details of the bottom which are truly amazing and which have given scientists a completely new idea of actual submarine topography. In addition to the bottom profile, however, the echo-sounder gives very good indications of the nature of the bottom as well as the layers underneath. For example, the recorded profile will indicate whether the bottom is mud, sand, or

rock and it can also penetrate short distances into the bottom to portray the thickness of the various sediment or rock layers.

22.2 Bathythermograph. One of the simplest yet most valuable oceanographic instruments is the bathythermograph (usually referred to by the initials BT) designed to record temperature versus depth. The device is operated by a tube filled with Xylene fluid which expands when heated. As a change in length of the tube occurs, it moves a stylus horizontally against a small smoked glass or gold film slide. Pressure is indicated in the vertical direction by a bourdon tube moving the stylus vertically with changes in pressure (depth). In this manner the stylus will move horizontally with temperature and vertically with depth (pressure) to produce a trace from which one can read the temperature at various depths.

The BT comes in two models for 450 ft or 900 ft depths, both of which can be lowered on $\frac{1}{16}$ inch steel cable by means of a small 300 lb winch. Successful readings are obtained at ships speeds of up to 15 knots but this is the upper limit for speed. Thanks to the BT we have a fairly good knowledge of the temperature structure of the oceans down to about 900 feet, the limit of the BT. Below 900 feet, which is really the largest part, we know less about the water column than we know about deserts or Arctic regions.

The shipboard BT is gradually being replaced for scientific work by thermistor chains, electronic BTs, and other more precise constant reading temperature devices. But it is still the primary tool for giving anti-submarine warfare (ASW) forces the environmental information needed for finding submarines. The BT gives a graphical indication of the depths of the mixed layer (direct sonar path), the thermocline (shadow zone) and special temperature conditions which may affect ASW search operations (see Fig. 22.7).

22.3 Nansen Bottles. As has been mentioned before the basic oceanographic measurements are temperature, salinity, and depth. In order to correlate all three values it is necessary that all three be recorded simultaneously at various depths from the surface to the bottom.

This can most easily be done by the use of Nansen bottles fastened at spaced intervals to a wire cable and lowered into the water. Each Nansen bottle consists of a special metal frame which can be secured to the wire cable at the desired places. The frame contains a glass bottle opened at both ends to hold about a quart (1.2 liters) of water sample, two or more reversing thermometers, and a releasing messenger. The cast is lowered into the water by means of a special oceanographic winch capable of paying out or hauling in 36,000 feet of wire cable. Each Nansen bottle, spaced at intervals along the cable, is in an upright position.

When the entire cast has been lowered into the water a messenger (small brass weight) is attached to the cable at the surface and released. When it hits the first bottle it trips a latch which causes the Nansen bottle to flop down into the reversed position thereby also releasing the bottle's messenger.

The messenger travels down the wire releasing the latch on bottle #2 and so on until all bottles in the cast have been reversed.

The reversing of the bottles is the key to the whole operation because at reversal two important events take place: the upper and lower valves of the bottle close, trapping a water sample; and the column of mercury in the special reversing thermometers is broken. The first ensures that the water sample is taken at the reversing depth and that the sample will not leak out or be contaminated with water from higher levels as the cast is hauled in. By breaking the column of mercury in the thermometers, one is able to read the temperature at the reversal depth.

As each bottle is brought on board it is placed in its proper order in a rack. When the entire cast has been recovered the work of analysis begins. Bottle number, location on cast, thermometer numbers, and depth by the winch revolution counter are recorded on special forms together with date, time, latitude, longitude, and ship's name.

For Nansen casts to the bottom of the ocean, six or more hours might be required just to lower and recover the entire cast. The ship must be dead in the water during this time. It takes another six hours to make the preliminary chemical analysis of all of the water samples, but during this period the ship can be underway for the next station 50 or 60 miles away.

22.4 Bottom Samplers and Trawls. A very important part of the study of the oceans is the collection of living animals swimming through the water or along the bottom and also the collection of cores or bottom samples to determine the structure of the bottom.

Living creatures in the sea range in size from microscopic plankton to giant whales. It is therefore necessary that trawls be designed in different sizes and shapes for best collecting one particular size of marine animal. In addition, the fishing industry uses a great variety of techniques for catching larger animals. Nets, hooks, intermediate trawls and bottom trawls are all used by fishing craft to catch the different species of fish for commercial purposes or for sport.

The nature of the bottom in relatively shallow water is important to all mariners since it determines the type of holding ground available for anchoring. Many other activities require specialized information on the bottom. International cable companies must have a knowledge of the bottom before laying the cable. The Navy must have a very detailed knowledge of the bottom because bottom reflections can extend the ranges at which sonar devices can detect submarines—provided the bottom structure and slope are also known. And lastly, but probably most important for the future, scientists must know bottom conditions in order to develop fully many scientific principles which are at present based solely on land observations.

The earth's surface is 70.8 percent water, yet scientists for years have been restricted to observations taken on the less than 30 percent surface area which is land. Many scientific disciplines such as geology, geophysics, seis-

mology, and geodesy are unable to expand their efforts into the ocean area because of lack of proper oceanographic instrumentation. Another complicating factor is that it is difficult to anchor a ship in 50 fathoms of water; one can therefore imagine the problems in anchoring a ship in more than 3000 fathoms of water.

The problem of taking bottom samples or cores in deep water is complicated by the fact that only isolated samples are possible and these penetrate only a short distance into the bottom. Subsurface currents cause the instrument to

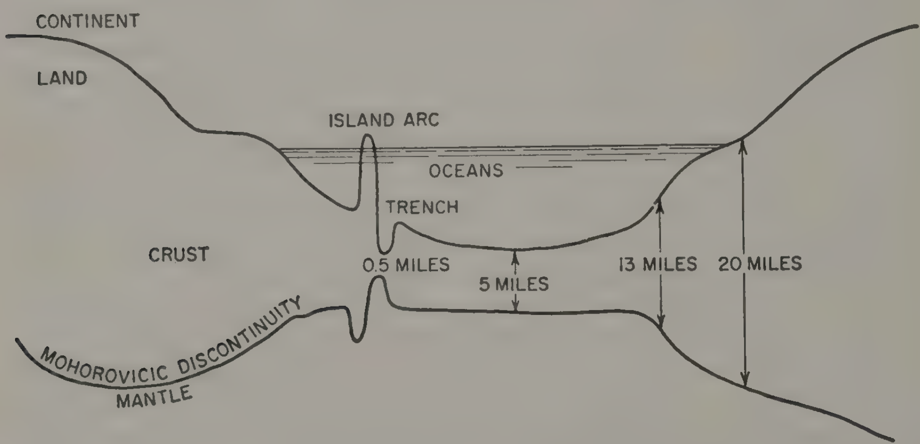


FIG. 22.3 THICKNESS OF EARTH'S CRUST UNDER LAND AND OCEAN. Under principle of isostatic equilibrium it is found that thickness of crust decreases as depth of water increases. Crustal thickness varies from 20 miles or greater over continents to 13 miles in shallow water, 5 miles in water of average depth (12,000 ft), and ½ mile in the deepest trenches (36,000 ft).

drift so that the exact spot where a bottom sample is taken is very uncertain. When one considers the error in ship's position possible with the celestial navigation techniques generally used in remote areas of the world, the exact position of deep ocean cores is probably not known within ±10 miles.

The first reliable deep ocean cores were taken by the "Challenger" Expedition in the early 1870's. These samples penetrated only two feet into the sediment, representing the last 85,000 years of geological history. Until the beginning of World War II little advance had been made in coring devices or techniques. Most cores of the pre-1940 era were less than ten feet in length.

The first great advance came in 1942 with the development of the Kullenberg corer, which used a piston inside the core barrel to help recover the sediment. This reduces the wall friction but still does not give a completely undisturbed core. Cores of about 65 feet can be taken with this device, but the Russians have reported that by modifying the Kullenberg corer they have been able to obtain cores down to 115 feet. This is an impressive achievement but still represents a very small part of the earth's crust.

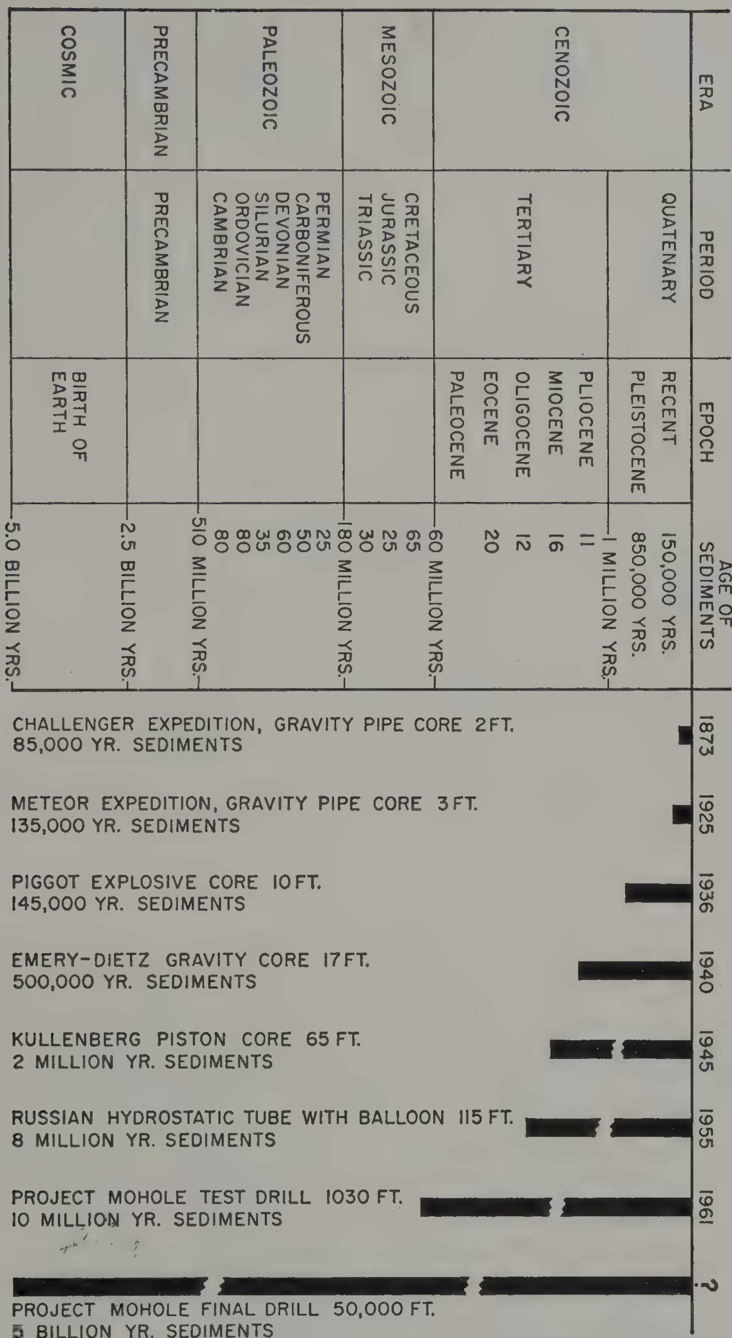


FIG. 22.4 DEPTHS OF VARIOUS TYPES OF CORES WITH THEIR CORRESPONDING AGE OF SEDIMENTS

The technology for drilling in deep water has been established by the test drills of Project MOHOLE which in 1961 successfully drilled in 12,000 feet of water to obtain a core depth of more than 1000 feet. This project is designed ultimately to drill through the earth's crust down to the MOHOROVICIC Discontinuity which is the boundary separating the earth's crust from the earth's mantle.

As can be seen from Fig. 22.3 the earth's crust is much thinner over the oceans than over land. Drills through continental land masses involve core depths of 100,000 feet where the earth's inner temperature is much too high for modern drilling equipment. The final drill site for Project MOHOLE will have to be one which meets acceptable standards for weather, sea and swell, depth of water, type of bottom, heat flow, currents, and, of course, proximity to supplies. Fig. 22.4 shows the depths obtainable by various types of cores, including MOHOLE, and the amount of geological history revealed in their sediments.

22.5 Ships and Deep Research Vehicles. Although not strictly speaking a tool, the most important device for oceanographic work at sea is the ship—the platform which carries the instruments, laboratories, and scientists needed to do scientific work at sea. Historically, oceanographic ships have been converted from passenger ships, cargo ships, yachts, men of war, and any other types of hull which were no longer required for their original purpose. These converted ships have done monumental work in the past and will continue to be useful for special purpose work for many more years.

In recent years, however, the work of the oceanographers has required so much specialized equipment that the electrical power and machinery on converted ships are no longer suitable. To combat this problem, the United States since 1960 has undertaken a large oceanographic ship construction program which by 1970 will see 100 modern specially designed ships doing scientific work at sea.

These ships will have among other things: large wet and dry laboratories; room for 15 or 20 scientists; stabilizing fins or anti-roll tanks to provide a level platform even at force 5 seas; gas turbines for absolutely quiet operations during acoustic measurements; center wells for lowering instruments from inside the ship, especially during poor weather; a fully equipped photographic laboratory; spaces for electronic computation and automatic data processing; and special electric power supplies with well regulated voltage and power. Special winches and deck handling equipment round out a modern oceanographic ship.

Another important oceanographic platform is the deep research vehicle (DRV), of which the U.S. Navy's bathyscaph, *Trieste*, has the deepest depth capability. Captain Jacques Yves Cousteau's *Turtle*, a 1000 foot depth vehicle, is the most productive in the shallower depth class. Unfortunately the *Trieste* has very little horizontal mobility—this is the price that must be paid in order to be able to go to depths of 36,000 feet.

The state of the art in the metallurgical industry is such that small two-man vehicles with a speed of about 5 knots and an endurance of 24 hours (120 miles) can safely be built only to go to depths of 6000 feet. For this reason, the U.S. Navy has developed a DRV Plan which calls for the construction of three classes of vehicles: the 6000 foot class utilizing present metallurgical techniques; a 15,000–20,000 foot class using aluminum, titanium, or other high strength materials still under study; and a modernized mobile version of the bathyscaph for investigating the deepest depths down to 36,000 feet.

There is a great deal of underwater engineering and scientific work which requires the use of DRV's. In areas where there are many submarine cables a DRV is necessary to take a human observer down to locate the cable to be repaired or recovered. Grappling techniques are too wasteful in regions of dense cable arrays.

Modern anti-submarine warfare involves erecting large sonar arrays on the bottom. A DRV is essential for a detailed inspection of the bottom since modern echo sounders cannot give the detail required for deep water placement of equipment. After the vehicle has inspected the bottom it will be needed to inspect the arrays, make minor repairs, or assist in bolting components together.

There are, in addition, requirements for the study of fish life, making geological surveys of the bottom, or recovery of missile nose cones and other underwater ordnance. The coming decade will undoubtedly see great advances in all facets of oceanographic instrumentation with the most spectacular results coming from the DRV's of the future.

Practical Results from Oceanography

There are many practical results from oceanography which cover the entire American economy but for the purposes of this discussion mention will only be made of those advances useful to a mariner.

22.6 Improved Charts. Before 1935, charts gave spot depths which were obtained by hand lead. With the advent of the continuous recording echo sounder a complete profile of the bottom is obtained. Since echo sounders are available for installation on everything from small power boats to huge aircraft carriers, it has become routine for most harbors to be well sounded.

There have been increased requirements in navigation charts, primarily by submarines. Before 1940 it was only necessary to know in detail depths less than 50 feet. This was adequate for surface navigation. During World War II submarine navigation required knowledge of depths shallower than 500 feet greatly increasing the area to be sounded. For modern deep diving submarines capable of travelling submerged at speed in excess of 25 knots, it is necessary to show every possible mountain peak or other danger to sub-

merged navigation. This means that the entire ocean area must be accurately charted.

22.7 Ice Predictions. In the late 1940's with the construction of the Distant Early Warning Net (DEW LINE) and air bases in Greenland and Alaska, many ships became involved in ice operations. Damage from ice exceeded $1,000,000 per year during the initial stages. In 1949 the U.S. Naval Oceanographic Office started a prediction program based on aerial observations and oceanographic factors such as currents and rates of ice formation.

The first predictions were understandably inaccurate but within five years highly accurate predictions were being made. At present it is possible to predict two or three weeks in advance of when a locality will be ice-free or iced-in. This enables planners to say when ships should leave U.S. harbors to be able to enter a Dew Line site with ice-free operations. It also permits ships to stay in the Arctic until the last possible day without fear of being iced in.

22.8 Weather Predictions. The oceans furnish almost 100 percent of the precipitation that falls on land in the form of rain, hail, or snow. They also play a major role in keeping the temperature of our planet within the narrow limits necessary for human development.

Moisture is introduced into the atmosphere at the air-sea interface. It is at this interface that wave action has its great effect by generating water droplets of the proper size for absorption into the atmosphere with later condensation as rain. In addition to droplet formation and other air-sea interface phenomena, oceanographers have provided the basic knowledge on hurricanes, typhoons, as well as other meteorological storms originating in the oceans.

But the most important benefit, improved weather predictions, comes from the mariner himself. Good weather forecasts depend on a dense reporting net. Ships at sea, by sending in periodic weather data, usually every six hours, provide meteorologists with the data network needed to provide accurate weather predictions.

22.8 Waves, Sea, Swells, and Breakers. Aside from the logistic difficulties of supplying a large force over a strip of beach, the major technical problem associated with an amphibious landing on an exposed coast is to determine whether the surf conditions along the beach would be suitable for small boat landings. To predict accurately the surf conditions at the time of hitting the beach required a great deal of oceanographic research. The successful wave and surf predictions for the World War II amphibious landings were based on the fundamental investigations carried out by physical oceanographers during the years between the Challenger expedition and the beginning of World War II.

There is a big distinction between waves, sea, swell, and breakers. The elements comprising a wave are illustrated in Fig. 22.5. All waves in a family are identical in shape, length, height, velocity, and period, although there is considerable difference between waves of different families. It must also be kept in mind that waves are not masses of moving water. The wave shape

moves while the individual water particles, except in cases where friction is involved, describe circular motions but remain essentially in place with little forward movement.

From Fig. 22.5 it can be seen that the distance between two successive wave crests is the wave length (L). The time in seconds for two successive wave crests to pass a point is the wave period (T). The speed of the wave in knots is given by the formula:

$$\text{Velocity (knots)} = \frac{\text{Length (feet)}}{\text{Period (seconds)}} \times 0.6$$

Waves can be generated in four fundamental ways in the open sea: by changes in atmospheric pressure, by wind acting for long periods on the water's

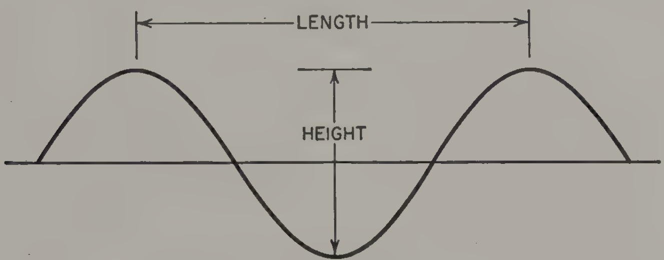


FIG. 22.5 ELEMENTS OF WAVES

surface, by seismic disturbances such as earthquakes, and by the tidal attraction of the sun and moon. These methods of generation act at different times, in different directions, and in different amounts. When waves of different characteristics meet in a small area, a complex pattern of wave motion results caused by waves reinforcing or interfering with each other in varying amounts. This complex situation is termed "sea" and is most difficult to describe mathematically.

When the waves have left the immediate area of their birth and are no longer being interfered with by waves with other characteristics, they assume a regular undulating motion which closely approximates the "ideal wave." This condition is referred to as "swell."

When waves enter shallow water the friction caused by the bottom will tend to slow down the water particles nearest the bottom while the upper particles continue with the faster original velocity. When the upper particles are travelling at a critical speed with respect to the bottom particles, the wave steepens and then breaks. This condition is referred to as "breakers." The area between the first breaking waves and the shore line is called "surf," a critical region in amphibious landings.

Basically the wave spectrum varies from short period wind-generated waves with periods of 3–30 seconds through long period tidal waves with periods of

about 12 hours 50 minutes. The term "tidal wave" refers to those waves generated by the action of the sun and moon on the oceans and should not be confused with seismic generated waves (tsunamis) which have erroneously been called tidal waves. The problem now facing oceanographers is to separate the different wave forms in the spectrum in order to analyze their motions.

From the mariner's point of view, the waves that most affect seamanship are those generated by the winds. It is common knowledge among seamen that the longer and harder a wind blows, the higher will be the waves. In order to forecast wave heights at a certain place, oceanographers must correlate a number of factors: wind speed and direction, fetch (the length of open sea over which the wind blows), and the duration of the wind. The predicted waves are later compared with the actual waves observed at a locality and analyzed in what is called hindcasting. The results of hindcasting are used to improve the forecasting techniques so that there is always constant feedback to develop a better system of prediction.

Since wind, fetch, and duration vary over wide values, it is necessary to develop special tables, nomograms, and slide rules to account for all of the possible variations. These special devices have been available for 20 years but are still undergoing constant revision and modification in order to provide the improvements indicated by the latest results of hindcasting.

Before closing this short discussion on waves, two points should be emphasized: there is a general tendency among all seamen to overestimate the heights of waves; and there is very little forward motion of the water particles in wave motion. With respect to overestimating the heights of waves, theory and observation are in close agreement that 50-foot waves are really about as high as one can expect to find at sea and that 70-foot waves, while statistically possible, are so improbable as to constitute a scientific rarity. (See Tables 22.5 through 22.10.)

TABLE 22.5. PROBABLE MAXIMUM HEIGHTS OF WAVES WITH WIND OF DIFFERENT STRENGTHS, COMBINED FROM VARIOUS OBSERVATIONS AT SEA WITH UNLIMITED FETCH

(Adapted from Krümmel)

Wind velocity (nautical miles per hour)	Wave height (feet)
8	2.6
12	4.6
16	7.9
19	11.5
27	19.7
31	24.6
35	29.9
39	36.0
43	39.4

TABLE 22.6. THE HEIGHTS OF WAVES, IN FEET, THEORETICALLY PRODUCED BY WINDS OF VARIOUS STRENGTHS BLOWING FOR DIFFERENT LENGTHS OF TIME

Wind velocity (nautical miles per hour)	Duration in hours						
	5	10	15	20	30	40	50
10	<2.0	2.0	2.0	2.0	2.0	2.0	2.0
15	3.5	4.0	4.5	5.0	5.0	5.0	5.0
20	5.0	7.0	8.0	8.0	8.5	9.0	9.0
30	9.0	13.0	15.5	17.0	18.0	19.0	19.0
40	14.0	21.0	25.0	28.0	31.0	32.5	33.0
50	18.5	29.0	36.0	40.0	45.0	48.0	50.0
60	23.5	37.0	47.0	54.0	62.0	67.0	69.0

TABLE 22.7. THE HEIGHTS OF WAVES, IN FEET, THEORETICALLY PRODUCED BY WINDS OF VARIOUS STRENGTHS BLOWING OVER DIFFERENT FETCHES

Wind velocity (nautical miles per hour)	Fetch (nautical miles)					
	10	50	100	300	500	1,000
10	<2	2.0	2.0	2.0	2.0	2.0
15	2.5	4.0	4.5	5.0	5.0	5.0
20	4.0	7.0	8.0	9.0	9.0	9.0
30	6.0	12.5	15.5	18.0	19.0	19.5
40	7.5	17.5	23.0	30.0	32.5	34.0
50	9.5	22.0	30.0	44.0	47.0	51.0

Based on a study of the basic energy relationships between wind and waves, by Dr. H. U. Sverdrup and Dr. W. H. Munk at the Scripps Institution of Oceanography. The calculated heights are the averages of about the highest 30 percent of the waves; these higher waves are of most practical significance, and the lower waves observed are likely to be of most recent origin.

TABLE 22.8. MINIMUM, MAXIMUM, AND AVERAGE HEIGHTS IN FEET OF WAVES FOR THE TRADE WIND BELTS

(After Krümmel, based on measurements by Paris)

Area	Minimum	Maximum	Average
Atlantic Trade Wind Belt	0	20	6
Indian Trade Wind Belt	3	16	9
Western Pacific, including the Trade Wind Belt	0	25	10

TABLE 22.9. MAXIMUM WAVE HEIGHTS THEORETICALLY POSSIBLE WITH VARIOUS WIND STRENGTHS, AND THE FETCHES AND DURATIONS REQUIRED TO PRODUCE WAVES 75 PERCENT AS HIGH AS THE MAXIMUM WITH EACH WIND VELOCITY

Wind velocity (nautical miles per hour)	Maximum wave height (feet)	75 percent of maximum height (feet)	Fetch for 75 percent of maximum height (nautical miles)	Duration for 75 percent of maximum height (hours)
10	2.0	1.5	13	5
20	9.0	6.8	36	8
30	19.0	14.3	70	11
40	34.0	25.5	140	16
50	51.0	38.3	200	18

TABLE 22.10. AVERAGE LENGTHS OF WAVES, OBSERVED AT SEA, ACCORDING TO THE STRENGTH OF THE WIND

(Adapted from Krümmel)

Beaufort scale	Wind description	Velocity (nautical miles per hour)	Waves, average length (feet)
2	Light breeze	11	52
4	Moderate breeze	20	124
6	Stiff breeze	30	261
8	Moderate gale	42	383
10	Strong gale	56	827

The supposed forward motion of wave particles is really an optical illusion. For hundreds of years, sailing masters have measured ship's speed through the water by the length of time it would take a chip of wood to float from the bow to the stern. In this case the wood is analogous (but not identical) to a wave particle—it remains stationary. The numerous valid cases on record of rocks or other submerged objects being moved by wave action can be explained by an energy transfer from the wave to the object or by special bottom currents generated by the waves. Submarines, on the other hand, can attest to the fact that at depths of 60 to 100 feet there is no appreciable motion of the submarine even while a raging storm is blowing on the surface.

22.9 Optimum Ship Routing. A significant advance in seamanship contributed by oceanographers is the Optimum Ship Routing Program developed by the U.S. Naval Oceanographic Office in 1958 but operated now by the Navy Weather Service. The reports on wave heights, received from thousands of ships at sea, are analyzed by trained forecasters working with high speed electronic computers.

These analysts prepare maps showing the range of wave heights throughout the oceans. (See Fig. 22.6.) It is then possible to route ships through

areas of minimum wave height, thereby providing a faster speed of advance. The Military Sea Transportation Service together with commercial lines who participate in the Ship Routing Program have been able to reduce voyage time by 10%. The New York-Bremerhaven run, for example, which took 10 days to complete in 1949 is now made in 9 days thanks to optimum Ship Routing.

In Fig. 22.6, track *A* is the great circle route from New York to Bremerhaven. Although this track is shorter in distance, it would involve for this

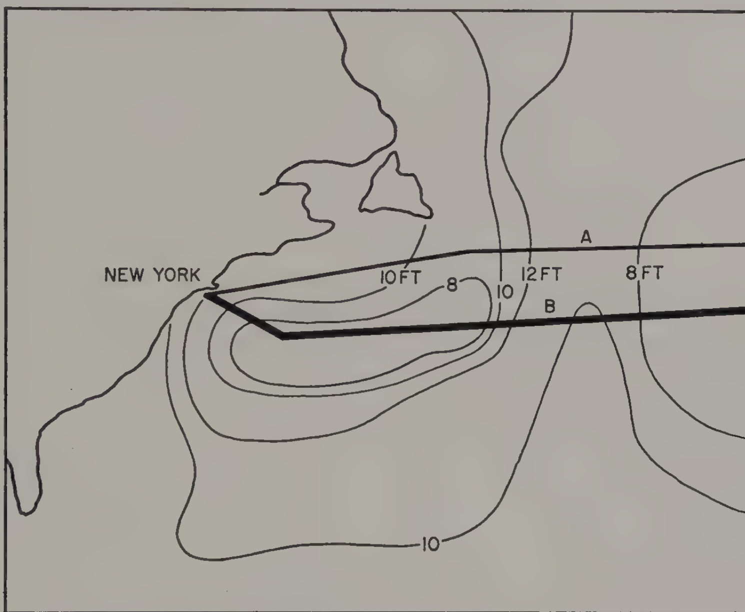


FIG. 22.6 OPTIMUM SHIP ROUTING WAVE HEIGHTS IN FEET

voyage going through areas where waves are 10 to 12 feet high. By routing the ships over track *B*, longer distances are involved but smaller waves are encountered. This results in a quicker and more comfortable voyage.

Reduced steaming time, decreased storm damage, and increased passenger comfort make the program important to cargo ships as well as passenger liners.

22.10 Currents. The earth's rotation generates the Coriolis force which is responsible for the clockwise oceanic circulation in the Northern Hemisphere. Since all ocean currents deviate to a greater or lesser extent from the Coriolis equations, it is the deviations from the predicted values that oceanographers must study so assiduously.

Much of our knowledge of ocean currents comes from the oceanographer's analysis of sea water samples and computation of dynamic height differences at numerous points in the ocean. This theoretical work has been supplemented

by current meter observations which are the basis of our present current charts and tables.

An interesting aspect of ocean currents is that for almost every surface current there is a subsurface current going in the opposite direction. Until 1957 current meters were not available to detect or measure subsurface currents. Oceanographers had predicted their existence but could not prove it. With the development of Dr. John Swallow's aluminum buoy it became possible to map these subsurface rivers. The first and most famous to be discovered was the Cromwell Current in the Central Pacific which runs east at 5 knots at a depth of several hundred feet while the surface current goes westward at 3 knots.

Since then a number of counter currents have been tracted with Swallow floats. These floats are made of aluminum which has a smaller compressibility than other metals so that they can be ballasted to float at any pre-selected depth. When equipped with a radio pinger the float can be tracked as it is carried along by the current. Information on subsurface currents is not only important for submarine navigation but also for mathematical studies on the heat budget of the oceans at different latitudes.

22.11 Shark Repellants and Anti-Fouling Paints. Barnacles and other organisms attach themselves to ships' hull and harbor pilings, reducing a ship's speed and weakening harbor facilities. Over $250 million is spent annually for repair of damage caused by these marine organisms.

Sharks do not cause nearly the same amount of physical damage as fouling organisms. Despite the great difference in size between sharks and fouling organisms, they do have one thing in common: a hatred of copper and copper compounds. For several hundred years shipbuilders have known that copper bottoms protected ships from the ravages of harmful marine life. Unfortunately copper sheeting is very expensive and rusts quickly away in salt water.

Chemical oceanographers, however, made use of the practical knowledge of shipbuilders by experimenting with copper chemical compounds to determine their effects on marine life. The results were so successful that now all modern anti-fouling paints as well as shark repellants carried in life boats are based on copper compounds.

22.12 ASWEPS. This is a Navy system whereby oceanographic reports are received from ships and fixed oceanographic buoys, the data analyzed and converted into short and long range oceanographic predictions. The word ASWEPS, standing for Anti Submarine Warfare Environmental Prediction System, indicates that the program's main application will be to provide fleet commanders with forecasts of oceanographic conditions so that ASW personnel will be better able to estimate sonar ranges, route convoys through areas of optimum sonar range, or to calculate a variety of naval problems including layer depth and weapon settings.

Figure 22.7 shows the complexity of the anti-submarine warfare environment which ASWEPS is designed to predict. The sketch portrays the major oceanographic problems in the detection, identification, localization, and destruction of submarines. Starting from left to right: the first column shows a typical bathythermograph (BT) trace of temperature vs depth. The temperature is constant down to a maximum of 400 feet. This zone is called the mixed layer. The temperature then normally decreases sharply until it reaches the

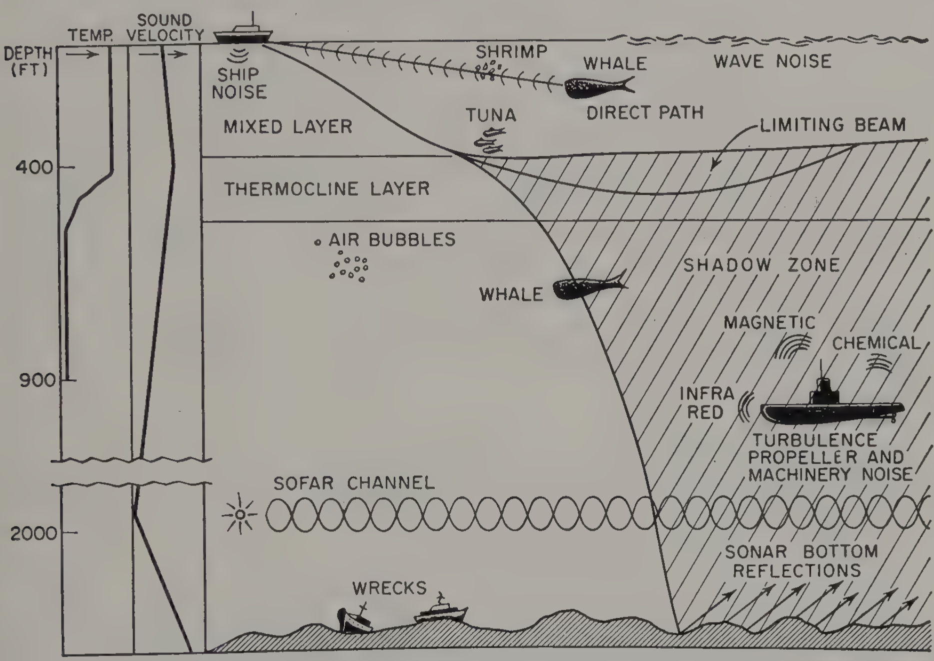


FIG. 22.7 THE ANTI-SUBMARINE WARFARE ENVIRONMENT

constant temperature of deep water (about 35°F). This is the region of the main thermocline. Note that the BT only goes down to 900 feet so that nothing is available to tell our ASW forces the temperature structure below 900 feet. Since submarines may be going to depths of 2000 feet by 1970, improved BT's are necessary.

The second column shows a plot of sound velocity vs depth. Sound velocity increases in the mixed layer because of the increased pressure but as temperature decreases in the thermocline so does sound velocity. At about 2000 feet depth the pressure effect exceeds the temperature effect and the sound velocity begins to increase again. The point of minimum sound velocity is the axis of the SOFAR CHANNEL.

In Fig. 22.7 the sketch to the right shows various noise sources in the oceans: own ship's noise, marine life, machinery noise from the submarine,

and surface wave noise. Whales or large fish can give a sonar return simulating a submarine. In the thermocline sound beams are for the most part bent upwards, giving a large area below which the submarine can hide.

Direct path sonar beams can pick up submarines in the mixed layer, but these beams do not penetrate into the shadow zone. Longer ranges into the shadow zone can be obtained through bottom reflection of the sound (also called bottom bounce) but use of this technique requires detailed knowledge of the bottom including slope, bottom composition, nature of the sedimentation layers under the ocean bottom, etc.

The submarine puts energy into the water in the form of machinery and propeller noise but also gives off chemical, infra red, magnetic, and other detectable signals. However, these signals resemble those of bottom wrecks, large fish or whales, air bubbles, and distant surface ships. The problem of separating the submarine's signal from the mish-mash of the background noise is formidable. When we consider that the submarine can change depth at will and can evade at speeds in excess of most surface ships, the problem of locating a high speed evading target in three dimensions becomes virtually impossible with our present knowledge of the oceans.

Figure 22.8 is another presentation of the first two columns of Fig. 22.7. It shows typical vertical distributions of temperature, salinity, density, and sound velocity.

Under actual conditions, these properties follow the *general* trends of the curves shown in Fig. 22.8 but with a number of smaller curves and wiggles to indicate the variations due to microstructure. It can be seen that temperature normally decreases with depth (sunlight does not penetrate too far into the oceans), salinity and density increase with depth (heavier material tends to sink and be found at lower levels), and sound velocity decreases because of decreasing temperature but at about 2000 feet begins increasing because of the effects of pressure and, to a minor degree, of salinity. This point, as mentioned before is the SOFAR CHANNEL axis. An explosive charge dropped in the SOFAR CHANNEL can be heard 10,000 miles away.

At present ASWEPS is being tested off the east coast of the United States with coverage also available in selected areas of the Pacific, Eastern Atlantic, and Mediterranean. Twice daily the ASWEPS forecasts are transmitted over the regular weather radio facsimile broadcast. Any ship equipped with radio facsimile receivers for reception of weather maps can also receive ASWEPS prediction charts.

The "facs" broadcasts at present are restricted to predictions of sea surface temperature and layer depth but this will be expanded to give forecasts of wave height, currents, as well as other data helpful to seamen. Within a few years, certainly by 1970, most of the ocean area will be covered by some type of prediction network to assist masters and commanding officers in laying out the best track to take advantage of favorable conditions to avoid harmful ones.

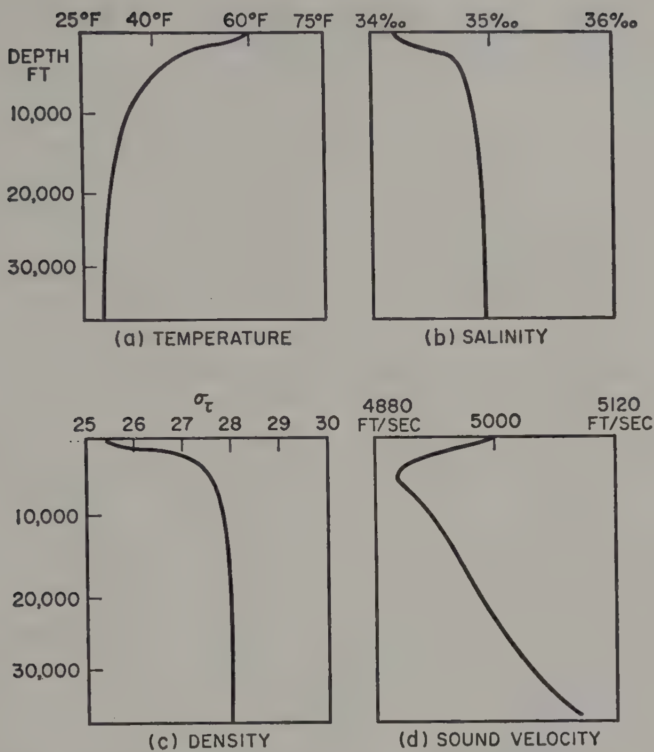


FIG. 22.8 VERTICAL DISTRIBUTION OF TEMPERATURE, SALINITY, DENSITY, AND SOUND VELOCITY

22.13 Harbor Flushing. Nuclear submarines and surface ships are now quite common so that the chances of accidentally contaminating a harbor with nuclear waste are proportionately greater. In order to minimize the harmful effects should an accident occur, detailed flushing studies have been made of all major harbors.

Anyone who has lived on a boat tied up at a marina knows that when the tide goes out it takes all of the garbage with it. Unfortunately, 12 hours later when the tide comes in so does most of the garbage that was removed on the last tide. The same effect will be had with nuclear or any other form of harbor pollution. The first tide will take out most of the pollution, but each succeeding tide will bring in a little and take out a little. Some areas of a harbor may be completely free of pollution after the first tide. Other areas, because of currents or other conditions, may retain serious levels of contamination for days or even weeks.

Flushing studies involve extensive investigations of all oceanographic conditions of a harbor: tidal information, currents, changes in bottom depth, nature of the bottom, location of eddies and backwaters, and similar data.

From these studies tables can be prepared to show how long it would take a harbor to become completely free of pollution.

22.14 Improved Fish Catch. A large amount of oceanographic effort goes into the study of fish life, including how marine animals are influenced by the oceanic environment. The fishing industry has received great benefits from this work.

Recent years have been the most prosperous in American fishing history thanks to the oceanographic research of the Bureau of Commercial Fisheries. Catches of salmon and shrimp have increased sharply since 1961. The tuna and New England groundfish industry have also done very well.

A necessary condition for successful competition with foreign fishing fleets, however, is superior knowledge of the sea and its inhabitants. Several interesting items have been discovered which are increasing our knowledge. For example, oceanographers discovered that extensive periods of northwest winds over the Grand Banks, especially during the mating season, will result in a reduced fish catch three to five years later. This happens because the eggs are driven by wind-generated ocean currents into deep water. Instead of dropping to the shallow bottom of the Grand Banks, they drop to the deep bottom of the continental slope, where they are crushed before they can hatch.

We cannot yet control such ocean forces but at least a study of the environment will tell us what to expect. In the case of tuna, it was discovered that they seldom go below the thermocline, the layer of temperature change. By taking bathythermograph readings, fishermen can tell at what depth the layer will be found and then can stream their nets or lines at the correct depth for the maximum catch.

Although temperature does *tend* to decrease with depth, there are important daily and seasonal changes (see Fig. 22.9). This typical seasonal tempera-

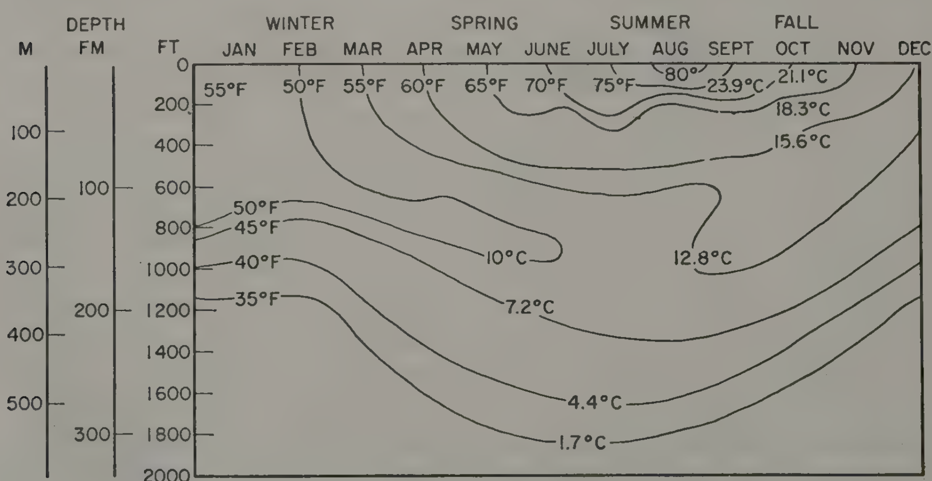


FIG. 22.9 TYPICAL SEASONAL TEMPERATURE CYCLE FOR NORTHERN TEMPERATE LATITUDES

ture cycle shows that isotherms (lines of constant temperature) are higher and closely spaced in the winter months but sink and become more widely spaced during the summer months. Since variation in temperature has such an important effect on sound propagation and fish environment, a detailed knowledge of daily and seasonal cycles is needed for naval ASW purposes as well as for civil fishing needs.

22.15 Tsunami Warning Net. One last but very important advantage derived from oceanography is the Seismic Sea Warning System operated by the U.S. Coast and Geodetic Survey for the Hawaiian Island area.

The Tsunami (often mistakenly called a tidal wave) is a seismic sea wave caused by earthquakes causing shifts in the sea bottom. The bottom movement starts waves travelling out, from a point on the surface above the disturbance, with speeds up to 500 miles per hour. Tsunami waves receive their initial energy from the tremendous energy of the earthquake and therefore have wave lengths many hundreds of times longer than those produced by the most powerful winds.

As the wave comes into shallow water the bottom part slows down due to friction of the bottom. This causes the upper portions of the wave to override the lower parts so that what would be an unnoticeable 1- or 2-foot swell in the open ocean, turns into a wave 50 feet high when a coastline is in its path. These waves come unannounced to wreak great havoc, especially in the Pacific which is ringed with volcanoes and earthquake belts.

The tsunami which hit the Hawaiian Islands in April 1946 took 173 lives, destroying $25 million worth of property. This tragedy led to the establishment of the Seismic Sea Warning Service, which already had a network of tide gauges located around much of the regional source of earth shocks. By adding a rapid communications network and tying the whole system into the network of seismology stations, the Coast Survey is able to predict arrival times of the waves and to issue advance warnings.

The system still is incomplete as can be seen from the 1964 tsunami which originated off Alaska and created so much damage along our west coast which is not covered by warning net. In 1960 another tsunami claimed 63 lives in Hilo, Hawaii costing over $23 million in property damage. More research will be needed until the network is operating at perfect efficiency but the problem should be well in hand before the end of the present decade.

Oceanic Phenomena

There is a wealth of information contained in the oceans, much of which is of practical importance to mankind. Some of these practical applications have been described above. But in addition to their utilitarian aspects, the oceans provide a vast source of intellectual knowledge useful to other sciences. For example, the coming and going of the Ice Ages can be traced by analyzing marine fossils.

We know with a fair amount of certainty that the average temperature was about 85 degree F some 200,000 years ago but that 25,000 years later it had dropped to 70 degrees F. This temperature drop was due to the Ice Age, but the method of tracing the extent of the glaciers by determining the temperature of the oceans thousands of years ago is a triumph of the scientific technique.

In 1947 Professor Harold Urey discovered that the ratio of oxygen −18 to oxygen −16 in shells and skeletons of marine animals can be correlated with the temperature in which the shells were formed. A difference of one hundredth of one percent (.01%) in the ratio of oxygen −18 to oxygen −16 in the carborates of the shells corresponds with a temperature difference of 1 degree F. By measuring the ratio difference in different layers of bottom cores, oceanographers can trace fluctuations in the ocean's temperatures back thousands of years. This use of radio-isotope techniques also enables oceanographers to tell that a fossil mollusc from a core was born millions of years ago in the spring when the water temperature was 72 degrees F, that it lived for about five years, and that it died in late summer.

Such techniques are only possible with highly developed instrumentation, the data from which can usually only be processed at large laboratories ashore. There are a number of interesting phenomena, however, which can be studied visually or with very simple equipment usually available on most ocean-going ships.

22.16 Deep Scattering Layer. A number of interesting phenomena are visible on the echo gram in addition to bottom depths features such as canyons, ridges, sea mounts or guyots. One of the most frequent and easily observed phenomena is the deep scattering layer. Ever since the first recording echo sounders, scientists have observed the smudgy trace that occurs on the recording chart at depths from a few fathoms below the keel down to 250 fathoms. The layer rises at night and sinks by day which could indicate some sort of biological phenomenon such as fish, shrimp, or other marine life. The fact that the deep scattering layer extends for hundreds of miles in unbroken stretches and in all oceans shows that it is not a regional or local phenomenon.

At present there is no certainty as to what causes the deep scattering layer. Theories have held that the layer was composed of Euphausiids, the shrimp-like animal which is the favorite food of whales, or of thick layers of plankton (microscopic plant and animal life). Unfortunately the numerous bathyscaph trips through the layer have not revealed any special abundance of marine life anywhere near the layer.

It is possible that if there were animals at the deep scattering layer they may have been frightened away by the light from the bathyscaph. It is also possible that marine life is not the cause of the layer. At present we have no workable theory of the cause of the layer but the latest bathyscaph studies indicate the layer may be caused by small air bubbles entrapped in the water which rise when the water is warmest (about two hours before sunset) and

become heavier and sink when the water cools. If this proves to be the correct answer to the mystery of the deep scattering layer, it will not be the first time that an apparently involved scientific problem was found to have a very simple solution.

22.17 Internal Waves and Dead Water. Whenever two layers of different density overlay one another there exists a possibility that waves will be created at the interface between the two layers. The most striking case of wave action occurs at the interface between the atmosphere and ocean where the density difference between air and water is a maximum.

The oceans, however, consist of other layers of different density. Whenever there are changes in temperature or salinity there are interfaces along which wave action can and frequently does occur. Within the ocean medium itself these waves are called internal waves. Their effect was known for hundreds of years during sailing ship days as dead water. However, it was not until this century that the laws governing dead water were understood.

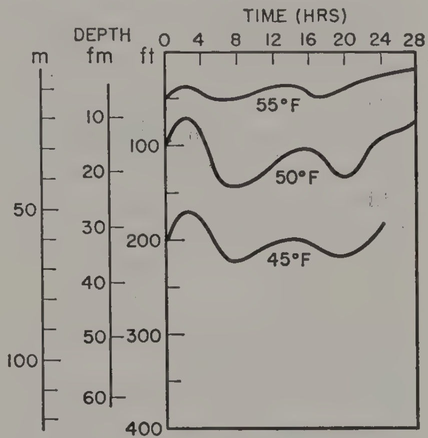


FIG. 22.10 INTERNAL WAVES FROM A PLOT OF ISOTHERMAL VARIATION

If the keel of a ship happens to be at the depth coinciding with the interface of two density layers, the ship's motion may set up internal waves. When this occurs so much energy from the ship's forward motion is used to generate the waves that nothing is left for forward motion. The result is that the ship is stopped dead in the water despite full sails and winds of 5–10 knots.

This was a not infrequent occurrence during sailing ship times and once, at least even affected the course of history. In the battle of Actium, Marc Antony's fleet was stopped by internal waves which contributed greatly to his defeat. Octavius won the battle and went on to become the Emperor Augustus, the first of the Roman Emperors.

The internal waves can easily be observed by taking temperature vs. depth readings as frequently as possible at any stationary point (see Fig. 22.10). A plot of the temperature readings versus depth will show that any one value (say 50 degrees F) will vary in depth with each reading. The amplitude of the depth changes in a temperature reading is the amplitude of the wave. The time interval between readings when a temperature value occurs at the same depth is the period of the wave.

Not much is known scientifically about internal waves but we do know that they can be dangerous to submarines. If a submarine passes through an in-

ternal wave from a heavy to a light density layer, it will suddenly find itself too heavy and will commence to sink. Contrariwise if it passes from a light to a heavy layer it will find itself too light and will rise to the surface. As any submariner can attest, sinking or broaching are not compatible with efficient operations.

22.18 Upwelling and El Niño. Under certain oceanographic conditions surface water will sink to a new level; under other conditions the water will rise from a lower depth to come to the surface.

Upwelling is important because it provides a constant circulation whereby nitrogeneous decay products from dead marine life are brought from the bottom to the surface. This fertilizes the ocean area involved, providing nourishment for marine life over wide ocean areas.

One of the most important areas for upwelling is along the West Coast of South America between the shore line and the northward flowing Humboldt Current. The upwelling brings up phosphates and other minerals from lower depths which in turn nourish plankton and fish life of all sorts. Birds come from long distances to feed on the fish and the islands where the birds' nests are filled with bird droppings, euphemistically called guano.

A third of a million tons of guano are sold yearly as high grade fertilizer. In the same area fishermen catch upwards of 100,000 tons of anchovies as well as substantial catches of larger species feeding on the anchovies. But every so often conditions change and the Humboldt Current meanders from its normal course.

When it does this, upwelling stops and a warmer current moves in from the north. The result is catastrophic. The fish population moves out to sea with the current, leaving the birds without a source of food. Up to 25 million birds may die in the famine with the hydrogen sulfide from their decaying bodies so thick that ships' hulls are turned black. This particular phenomenon is called the "Callao Painter" but the overall phenomenon causing the upwelling to stop is called El Niño, one of the most destructive oceanographic conditions in existence.

22.19 The Red Tide. The same atmospheric conditions which affect the prevailing winds causing the Humboldt Current to wander further out to sea are also responsible for another destructive occurrence known as the Red Tide. When upwelling stops, cool waters are no longer brought to the surface. The surface layers become heated, which brings about a bloom of tiny red-colored plankton. The tiny plankton becomes so thick that the water actually takes on a reddish hue—hence the name Red Tide.

The result of the Red Tide is that millions of fish are suffocated by the tiny organisms clogging their gills. Their dead bodies are thrown up along miles of beaches with a stench that carries for miles. Although not as economically destructive as El Niño, the Red Tide does cause severe hardships along the coasts where it occurs. Only a few years ago it occurred off the coast of Florida

with the unhappy result that hundreds of resort towns were forced to close down until the tide had passed and its debris was cleared away.

22.20 The Black Sea. There is one last phenomenon to discuss and that is the hydrogen sulfide content of the Black Sea between Russia and Turkey. The Black Sea is a very large salt water lake whose only opening is through the Straits of the Dardanelles.

The sill between the Black Sea and the Aegean is very shallow and narrow so that there is a minimum exchange of water between the two seas. This lack of exchange has a very harmful effect: it prevents any reasonable amount of upwelling so that as marine life on the surface dies it sinks to the bottom where it remains to decay.

Over a period of hundreds of years the decayed matter gave off hydrogen sulfide gas which completely destroyed all bottom life. The hydrogen sulfide layer begins at a few hundred feet in depth and continues to the bottom. In this region there is no life in the Black Sea.

From a naval point of view the Black Sea poses a very interesting problem. When mixed in water the hydrogen sulfide gas has a corrosive effect on metals as can be seen from the "Callao Painter" effect during El Niño, mentioned above. A submarine operating for extended periods in the hydrogen sulfide zone would run serious risk of ruined hull fittings with attendant risk to the ship and its crew.

Oceanography is a vast field, but one which is of vital importance to all mariners. This short chapter could only touch on the high spots with emphasis on the safety at sea aspects of oceanography. There are many worthwhile books that can be read by the mariner and many important observations that can be made with relatively simple and unsophisticated equipment.

A fuller description of oceanography is available in the following references:

a. Cowen, Robert C. *Frontiers of the Sea*. New York: Doubleday, 1960.
b. Long, E. John, Capt., USNR (Ret.), ed. *The Ocean Sciences*. Annapolis, U.S. Naval Institute, 1964.
c. *Oceanographic Observations at Sea*. H.O. Pub. 606 a-e (a series of Oceanographic Office Pamphlets describing how to record various observations).
d. *Oceanography, The Ten Years Ahead*. I.C.O. Pamphlet No. 10, June, 1963.
e. *Processing Oceanographic Data*. H.O. Pub. 614.
f. Sverdrup, H. U., Johnson, M, W., and Fleming, Richard H. *The Oceans*. Englewood Cliffs: Prentice-Hall, 1942.
g. Williams, Jerome. *Oceanography, An Introduction to the Marine Sciences*. Boston: Little, Brown, 1962.

23

The Atmosphere and Its Circulation

23.1. Introduction. Man lives at the bottom of an ocean of air, the atmosphere, whose state changes by the day, the hour, even the minute. The state of the atmosphere at a given time and location is what man calls weather. Climate is what he calls the average weather conditions for an area over a period of years. Meteorology is the science which deals with the nature of the atmosphere, its changes, and reasons for the changes.

During the present century, meteorology has developed along sound scientific and mathematical lines so that today much is known not only about local conditions as they exist in many parts of the world but about the causes of weather as well. Experience has always been and still is necessary in forecasting weather, but modern developments have done much to put the subject more nearly on a sound scientific basis.

The weather section of this volume is directed to those who, although not undertaking to be their own forecasters, should be able to understand the advice of the professional in order to make full use of existing weather facilities, to interpret conditions in the absence of information, to develop the ability to supplement official broadcasts with personal observations, and to make intelligent decisions on the basis of existing information. This section, therefore, will present some of the fundamental modern concepts of the physical processes which cause weather, along with descriptive weather information, which will afford a basis upon which to build further knowledge through observation and reference to literature on the subject.

The *United States Coast Pilots* and the *Sailing Directions* published by the Coast and Geodetic Survey and Navy Department, respectively, contain much descriptive material of the weather and climate to be found along our coasts and in many parts of the world. Such subject matter should be read by those operating in the areas concerned. Also the monthly *Pilot Charts* published by the Oceanographic Office of the Navy Department contain a mass of useful information concerning prevailing winds, fog, ocean currents, and average weather conditions. On the backs of many of these charts are special articles on such topics as hurricanes, water spouts, fog at sea, icebergs, and other phenomena.

The *U.S. Navy Marine Climatic Atlas of the World* is a series of studies which presents meteorological and oceanographic information for the surface and upper-air over the ocean areas of the world. Users will find this series of

publications most helpful in weather studies of and operations over the ocean areas.

23.2. The Atmosphere. The atmosphere, the mixture of gases which surrounds and is bound to the earth by gravitational attraction, extends to an indefinite height. It is still dense enough at 600 miles above the earth to yield auroral effects; the extreme upper limit would be 18,600 miles, where a gas molecule would no longer be held in orbit by the earth's gravitational attraction.

The atmosphere tends to be divided by its vertical temperature structure into a series of concentric shells, as shown in Figure 23.1. From the standpoint of meteorology, the two significant layers are the troposphere, where the temperature averages 1 degree F lower with each 300 feet of added height, and the stratosphere, where the air temperature remains nearly constant at about −67 degrees F through a 5-mile layer. The troposphere and stratosphere are separated by the tropopause, the level at which temperature stops decreasing with height. The tropopause height varies with season, latitude and weather conditions. It is higher over the equator than at the poles. At any given latitude, it is higher in summer than in winter, and higher over stormy areas than over regions of settled weather.

Other features of the troposphere are:

1. It has both horizontal and vertical air circulation.
2. It is the region to which are confined such phenomena as storms, precipitation, changing weather conditions, and nearly all clouds.
3. About three-fourths of the mass of the atmosphere is contained in the troposphere.
4. Its average upper limit is about 7½ miles above the earth's surface, but it varies from about 10 miles at the equator to about 5 miles at the poles.
5. The troposphere contains water vapor in varying amounts from less than 1 percent up to 5 percent by volume.
6. The troposphere is compressed and therefore quite dense as compared with the stratosphere. In the lower levels of the troposphere atmospheric pressure is approximately 1 inch of mercury less at each 1000-foot interval above the earth's surface.
7. Flying conditions may be poor. Icing, rough air, poor visibility, cloud ceilings, and thunderstorms are common in the troposphere.

Essential characteristics of the stratosphere are:

1. A nearly constant temperature of −67 degrees F exists for a considerable distance upward from the base of the stratosphere.
2. Vertical air motion occurs only in shallow waves, although strong winds exist.

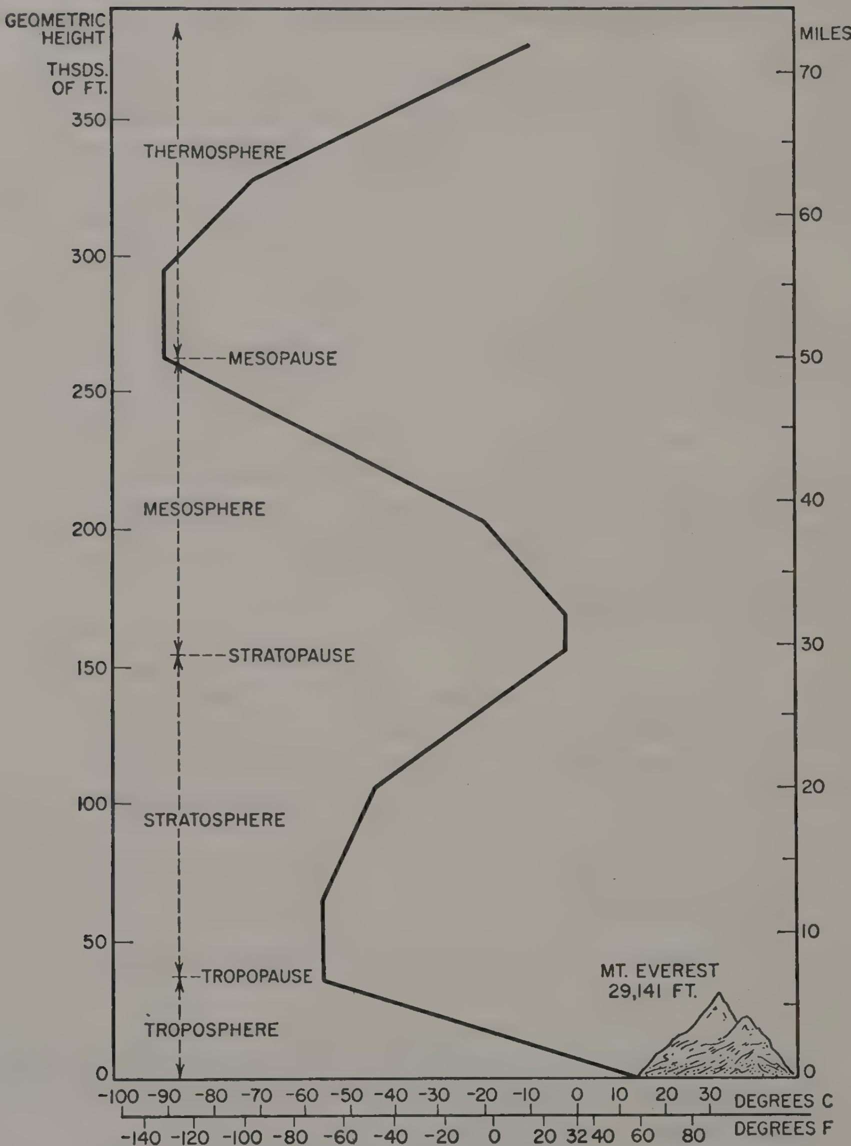


FIG. 23.1 THE UPPER ATMOSPHERE. *Navy Weather Research Facility*

3. Very little water vapor is found in the stratosphere; clouds are virtually nonexistent.
4. Favorable flying conditions prevail.

23.3. Composition of Air. Figure 23.2 shows the approximate percentages by volume of the principal constituents of the air. Throughout the troposphere air is composed of a mixture, not a chemical compound, of about 77 percent

nitrogen, 21 percent oxygen, 1 percent water vapor, 1 percent argon, and less than 1 percent carbon dioxide. There are also traces of a number of other gases, dust, smoke, and salt particles, which are important in weather processes. Nitrogen seems to serve as a diluting agent for the oxygen. Oxygen is necessary for animal life and combustion. Carbon dioxide is essential to plant life. Water vapor is the most important atmospheric constituent from the weather standpoint. It is an invisible gas, but often condenses to form liquid water. This condensation process may cause precipitation, fog, dew, frost, rough air, and other weather changes. The energy released by the condensation process may be involved in creating violent, vertical currents and intense storms.

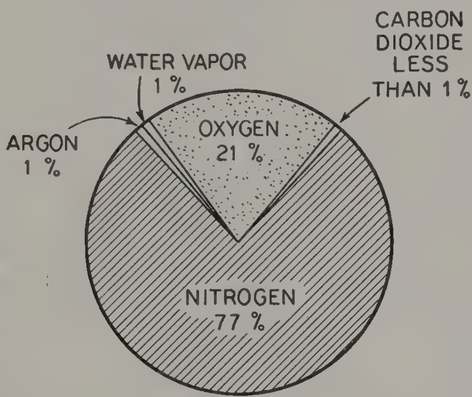


FIG. 23.2 AIR—A MIXTURE OF GASES. Nitrogen predominates; each has a function; but water vapor is the most important in weather and climate phenomena. The percentages by volume are indicated, but the percentage of water vapor may vary from less than 1 percent to about 5 percent.

Although water vapor usually composes only about 1 percent of the air, it may be present in an amount ranging anywhere from near nothing to 4 or 5 per cent. Air temperature determines the maximum percentage of air which may be water vapor. For example, it might compose 5 percent of the volume of warm air, whereas the greatest amount which could exist in cold air is a much smaller percentage. If air contains the maximum amount of vaper possible at a given temperature, cooling of the air or addition of more water vapor would immediately result in the condensation of some of it. This means that some of the invisible water vapor would change to visible liquid or solid form. When air is cooled, the temperature at which condensation on a smooth polished surface begins to occur is known as the *dewpoint.*

There is always at least a small amount of vapor present in the atmosphere. When air contains the maximum amount possible at the existing temperature, the air is known as saturated. The term is rather misleading, as saturated air, even at warm temperatures, never consists of more than a small percentage of water vapor by volume. Air which does not contain enough vapor to cause saturation at the existing temperature is known as unsaturated air. When

dense fog exists, the air is not only saturated, but it contains condensed water vapor (fog particles) as well. The relative humidity then is 100 percent. *Relative humidity* is the ratio of the amount of water vapor in the air to the amount the air could hold at the existing temperature. When the air temperature increases 20 degrees F, the capacity of the air for water vapor approximately doubles; therefore, air at 80 degrees F can hold 16 times as much as air at 0 degrees F.

It is now believed that the gaseous constituents of the stratosphere and their percentages are the same as in the troposphere, with the exceptions of water vapor and ozone. Water vapor is virtually nonexistent in the stratosphere. Ozone (triatomic oxygen) is concentrated in very small but still significant amounts in the layer 12–20 miles above the ground. Because of its radiation absorption capacity, it is important to the radiation balance of the upper atmosphere, and protects living things on the earth from excessive ultraviolet radiation from the sun.

In the troposphere the percentages of oxygen and nitrogen remain about constant because of the circulation and mixing of the air. Since there is little vertical motion of the air throughout the stratosphere, it is believed that the percentages of the various gases there remain constant because of molecular diffusion. If some such process were not in operation, the gases would tend to separate into layers, with the heavier gases settling toward the lower portion of the stratosphere.

Air even at high levels and far inland contains large numbers of salt particles which have been carried away from the sea by the winds. These, together with other so-called hygroscopic particles, such as soot, smoke, etc., provide important nuclei necessary for the formation of raindrops. Such particles also affect the visibility and are a factor in sky coloring.

23.4. Heating and Cooling of the Atmosphere. Heat is transferred in three ways: by *radiation*, by *conduction*, and by *convection*. The sun sends forth a constant flow of energy which reaches the outer limits of our atmosphere in the form of short-wave radiation. From 35 to 40 percent of this incoming radiation is reflected back to space, while the remainder, except for a small part absorbed in the atmosphere, is absorbed by and heats land and water at the earth's surface. Some of this earth-trapped energy is reradiated as long-wave radiation. Part of it heats the atmosphere; the remainder returns to space. Water vapor, the principal heat-absorbing constituent of the atmosphere, absorbs the outgoing long-wave radiation more readily than the incoming short-wave, causing the atmosphere to act as a heat trap like the glass of a greenhouse.

The loss of energy from the earth's surface and atmosphere must balance incoming solar radiation, or we would be faced with the chilling prospect of trying to survive on an earth which would get colder or, worse, an earth turned incandescent, since the temperature would rise on an average of around 3 degrees F per day if all the solar radiation were trapped.

Radiation is not the only means by which the atmosphere is heated. Air in immediate contact with warmer water or land surfaces is heated by means of conduction. Conduction alone is effective in heating only that portion of the atmosphere which is adjacent to the earth. Convection can carry heated portions of surface air to upper levels of the troposphere. When a mass of air at the earth's surface becomes heated by conduction, it expands and becomes lighter per unit volume. It is then underrun by surrounding colder, denser, and heavier air and is pushed upward. It rises and its heat, acquired at the earth's

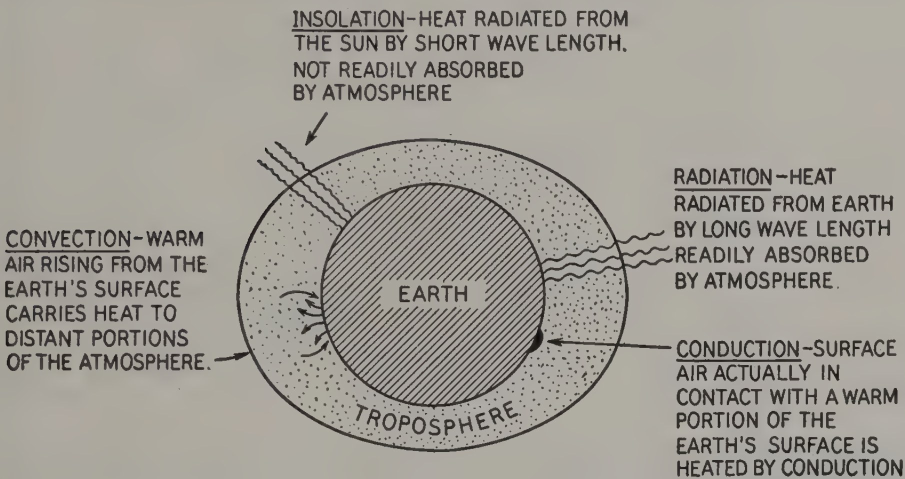


FIG. 23.3 MEANS BY WHICH THE ATMOSPHERE MAY RECEIVE HEAT: (1) Radiation, (2) conduction, and (3) convection

surface, is carried to higher levels. The colder air from above, which replaces it at the surface, is heated in turn and eventually rises to upper levels. Examples of convection, conduction, and radiation are shown in Fig. 23.3.

23.5. Atmospheric Pressure. Air is light, but the total weight of the atmosphere is enormous. If the weight of all the air were replaced by the same weight of ordinary water, the globe would be covered with a layer 34 feet deep.

At sea level, the average pressure exerted by the atmosphere amounts to 14.7 pounds per square inch, or a column of air one inch in cross section extending from sea level to the upper limit of the atmosphere weighs 14.7 pounds. Pressure decreases with height in the atmosphere; at 18,000 feet it is only half the sea level pressure, one quarter at 36,000 feet.

The atmospheric pressure due to oxygen decreases proportionately with height, so that man has normal respiration only to about 13,000 feet. At 30,000 feet, he will become unconscious in about 73 seconds. Near 52,000 feet, man, in a manner of speaking, drowns in his own water vapor, because at this height and at normal body temperature the lungs become filled with carbon dioxide and water vapor; there is not enough pressure for any oxygen to enter the

lungs. Above 63,000 feet, the pressure is so low that body liquids begin to boil at ordinary blood temperature.

In meteorology, air weight, or atmospheric pressure, is usually expressed in terms of the length in inches of a mercury column or in millibar units. These units will be considered later in connection with barometers. Fourteen and seven-tenths pounds per square inch are equivalent to 29.92 inches of mercury or to 1013.25 millibars.

Atmospheric pressure at any location constantly changes, and it varies from place to place. These variations in pressure values are due to changes in tem-

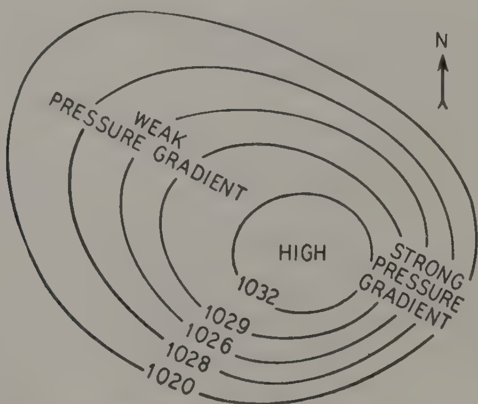


FIG. 23.4 AN AREA OF HIGH PRESSURE CENTERED AT "HIGH." In the southeast quadrant of this "High" the isobars are close together, and the pressure gradient is known as strong; at the center and to the northwest, the gradient is weak.

perature. When air is warmed, it expands, becomes less dense, and the atmospheric pressure is reduced. Conversely, when air becomes cold, it contracts and becomes more dense, or heavier. Areas having cold masses of air will record higher atmospheric pressure readings.

Lines drawn on a map through points on the earth having the same atmospheric pressure are known as *isobars*. These lines of equal pressure enclose areas of high and low pressure on weather maps. Horizontal *pressure gradient* refers to the decrease per unit distance in a horizontal direction perpendicular to the direction of the isobars. In Fig. 23.4 the isobars are seen to be spaced closer together in the southeast portion of the high pressure area than in the northwest section. When isobars are close together, the situation is known as a steep pressure gradient, but when they are far apart, the gradient is weak.

23.6. Wind Speed and Direction—Causes. Speed of the wind is determined primarily by the pressure gradient. Strong gradients cause strong winds; the horizontal pressure gradient force is inversely proportional to the isobar spacing.

For any given pressure gradient the wind blows stronger over water areas

than over land. This is due to less friction, which is usually greater over land than water. Hills, trees, buildings, and similar objects retard the speed of the wind more than do water surfaces. The earth's frictional effect can be detected as high as 3000 feet with strong winds and exceptionally rough terrain, but ordinarily the effect does not exist at heights over 1500 feet above land and water surfaces. For this reason the wind speeds are generally higher at elevations above the surface frictional layer.

Wind direction depends chiefly upon the direction of the pressure gradient and the rotation of the earth. Let us first consider the effect of the pressure

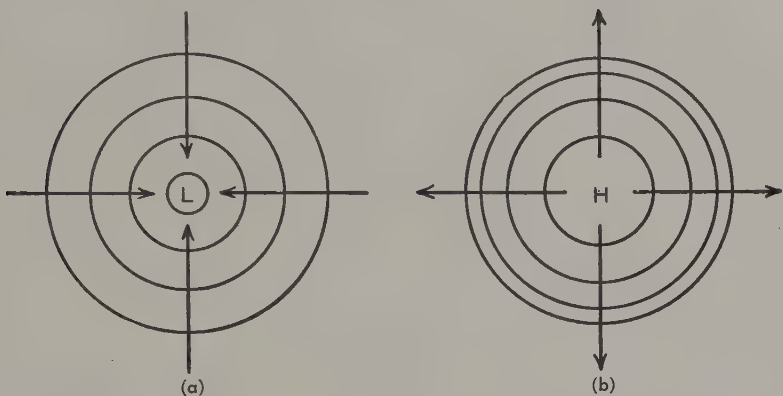


FIG. 23.5(a) AIR FLOWS TOWARD REGIONS OF LOW PRESSURE. Were it not for the apparent deflective force due to the earth's rotation, air would tend to flow directly toward points where pressures are the lowest.

FIG. 23.5(b) AIR FLOWS AWAY FROM REGIONS OF HIGH PRESSURE. Wind direction would be parallel to the gradient as shown, were it not for the earth's rotation.

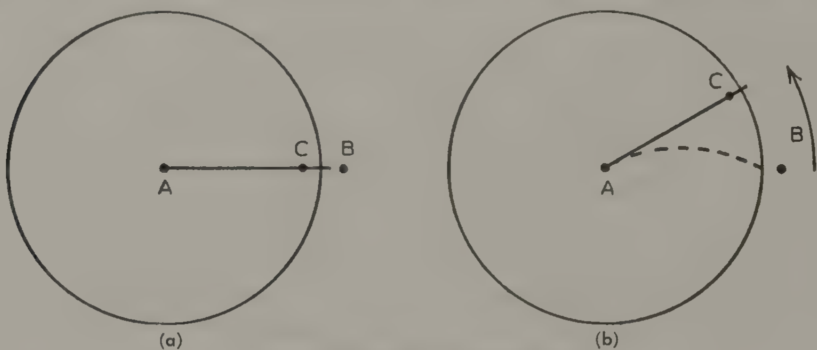
gradient. Figures 23.5(a) and (b) show the tendency of air to flow from a high pressure area to a section where the pressure is lower. This flow of air we know as wind, and it tends to blow parallel to the pressure gradient, i.e., at right angles to the isobars. However, due to the rotation of the earth, the wind is deflected to the right in the northern hemisphere and to the left in the southern hemisphere.

Wind deflection caused by the earth's rotation is known as the *Coriolis effect*. Fig. 23.6(a) shows a disk rotating to the left counterclockwise. Let us assume that air starts to move in a straight line from A toward points B and C, with B located just off the edge of the disk, C located at the edge of the disk. Assume, also, that point C on the disk rotates 30 degrees to the left during the time that it takes the air to move from A to B. Figure 23.6(b) shows the curved path which the air would take over the rotating disk to reach B. To see this clearly, cut a disk of paper and fasten it with a thumbtack at the center to a board. Make an X on the board just off the disk. Place a pencil point at the center of the disk and draw a line slowly toward X, at the

same time rotating the disk slowly in a counterclockwise direction. The pencil line will curve as in (b).

If the disk is rotated toward the right, a particle in motion on it would appear to be deflected toward the left.

The plane of the horizon of an observer located any place in the northern hemisphere rotates toward the left with reference to a point in space. Therefore the plane of the horizon may be likened to the plane in (b), and air in motion in any direction on the earth north of the equator is deflected to the right. In the southern hemisphere wind from any direction is deflected toward



CORIOLIS FORCE DEMONSTRATED

FIG. 23.6(a) Air starts to move from point *A*, located on a disk which is rotating counterclockwise, toward point *B* which is located just off the disk. As the air leaves point *A* it is also headed toward point C on the edge of the disk.

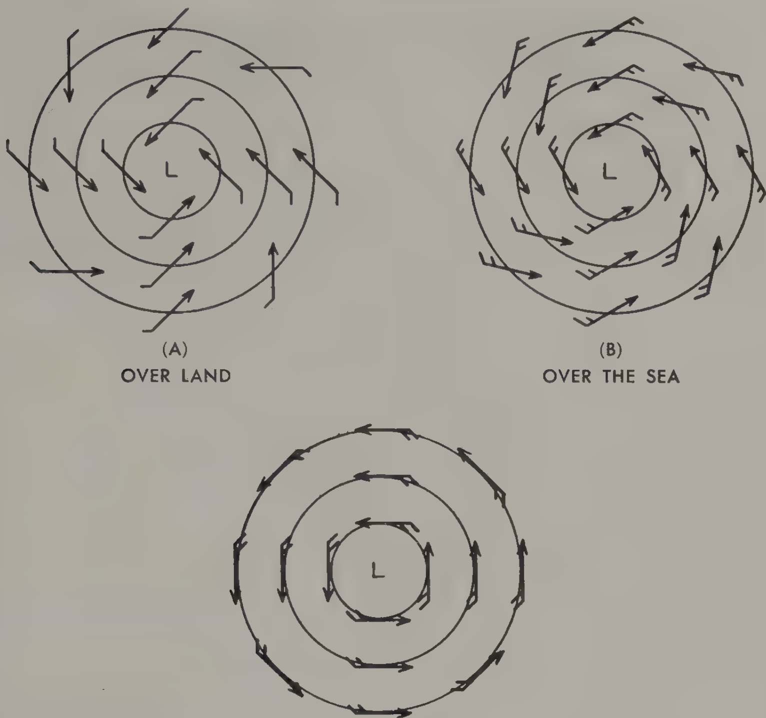
FIG. 23.6(b) The disk rotates through an angle of 30 degrees as the air moves across the disk from *A* to *B*. The air, because it is headed toward *B*, does not reach point C. Though the air moves directly from *A* to *B* its path appears as a curved line to an observer on the disk.

the left. This is because the observer's horizon in the southern hemisphere rotates in a clockwise manner, or toward the right.

The Coriolis force is perpendicular to and directly proportional to the pressure gradient. It is strongest in polar regions but is zero at the equator. At intermediate latitudes it varies directly as the sine of the latitude.

A third effect of importance in determining wind speed and direction is friction. Friction retards air movement; the degree depends upon the nature of the surface over which the air is moving. It is least over water and greatest over mountainous terrain (Fig. 23.7).

Friction causes surface winds to flow across the isobars instead of parallel, as it would do when pressure gradient and Coriolis forces are in balance. Figure 23.8 shows the effect of friction. It acts in a direction opposite to the actual wind and slows it down. The Coriolis force is proportional to wind speed so, with friction entering the picture, it is not able to balance the pressure gradient force. Instead, the pressure gradient force is balanced by the force resulting from the combined friction and Coriolis forces, and the actual wind



(A)
OVER LAND

(B)
OVER THE SEA

(C)
MORE THAN 1,500′ ABOVE THE EARTH

FIG. 23.7 With similar conditions of pressure gradient, wind velocities are greater over the sea than over land; at elevations above 1,500 feet wind velocities are greater than at the surface. It is also apparent from the figures that the wind blows parallel to the isobars at elevations above 1,500 feet; it makes an angle of 10 to 20 degrees over the sea; over the land the wind makes an angle with the isobars which averages about 30 degrees.

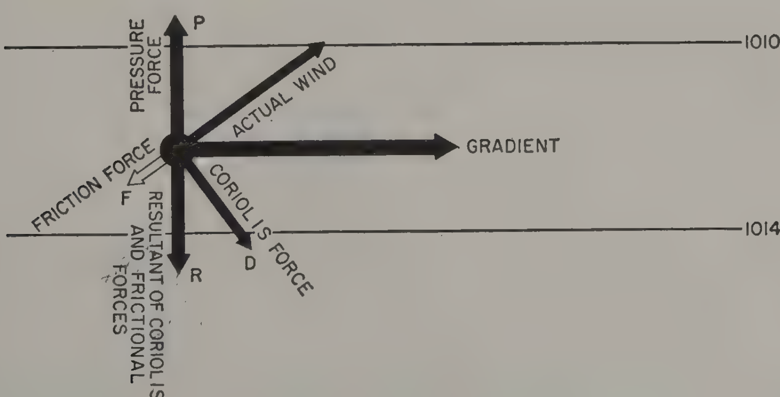


FIG. 23.8 FRICTIONAL FORCE EFFECT

blows across the isobars toward lower pressure. Since friction decreases with height, we would expect (and find) that the winds gradually turn with height until, above the friction layer, they blow along the isobars. Speed increases gradually as friction decreases.

23.7. General Winds of the Earth. Uneven heating of the earth's surface causes differences in atmospheric pressure which, in turn, cause winds. Equatorial regions of the earth receive considerably more heat than do the polar areas. Figure 23.9 illustrates the effect of direct and oblique rays. This excess

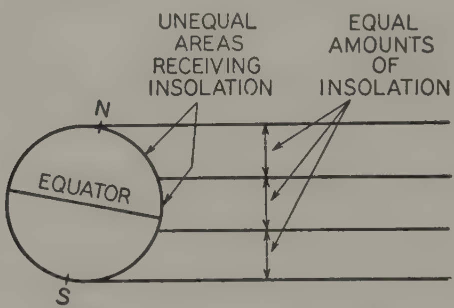


FIG. 23.9 The sun's rays reach the earth's surface more obliquely in polar regions than in the tropics. This causes unequal heating of the earth's surface. It will be noted that equal amounts of insolation affect unequal areas of the earth's surface.

of heat at the equator is the basis of a definite world wind pattern. On a nonrotating globe of homogeneous surface the system would be simple. The atmosphere, having been warmed and expanded over the hot equatorial belt, would flow poleward at the higher levels of the troposhere. This would tend to increase polar surface atmospheric pressures. Air then would tend to flow away from the poles and along the earth's surface to the equatorial girdle of lower pressure. This simple circulation is shown in Fig. 23.10. Such a circula-

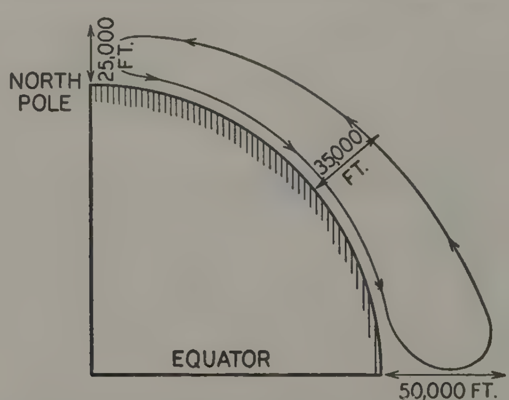


FIG. 23.10 THEORETICAL PATTERN OF WIND CIRCULATION DUE TO THE UNEQUAL HEATING OF THE EARTH'S SURFACE. Actually this scheme is considerably modified because of the rotation of the earth, the influence of oceans, continents, and other factors. (*After Rossby*)

tion is impossible because of the influence of the earth's rotation. The world wind system is further complicated by the contrasting temperatures of continents and oceans and by many other local causes which will be considered in order. Refer now to Fig. 23.11.

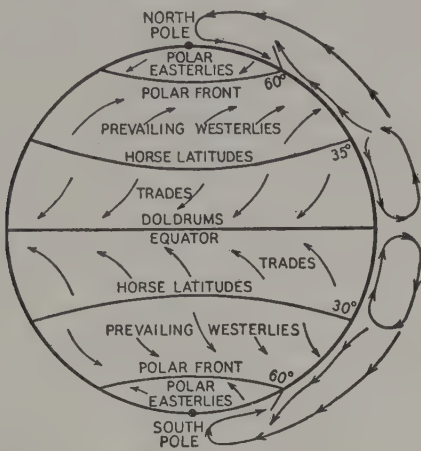


FIG. 23.11 GENERAL PATTERN OF WORLD WINDS

23.8. The Doldrums. The girdle of low atmospheric pressure in the region of the equator where the trade winds from the Northern and Southern Hemispheres converge, is known as the doldrums or Intertropical Convergence Zone. This zone shifts slightly north and south with the seasons, and its mean position is somewhat north of the equator. It is characterized by light and variable surface winds and frequent calm conditions. Warm temperatures and associated rising air currents are quite general. Cloud types are the bulging, piled-up cumulus, and cumulonimbus (thunderhead). The air is sultry, and showers and thunderstorms are frequent. The sky is often overcast. Average annual rainfall is heavier than that of any other latitudinal belt.

23.9. Sub-Tropical High Pressure Belt or Horse Latitudes. In considering the world wind system, conditions which exist in the northern hemisphere will be described first, then differences found in the southern hemisphere.

Air rising over the doldrums flows poleward in the high levels of the troposphere, but it does not blow directly north. The Coriolis effect causes it to be deflected to the right, and it becomes a southwest wind. In fact, at about latitude north 35 degrees it is supposed that the deflecting effect of the earth's rotation causes the wind at high levels to blow approximately from west to east, although the wind circulation at high levels is not nearly as well understood as conditions at the earth's surface. This deflection of the wind to the right causes the air to tend to pile up at about 35 degrees north latitude. The result is a ring of high pressure which extends around the earth at that latitude. The cooling of the air as it flows northward at high levels and its conse-

quent shrinking and sinking contribute to the high-pressure belt. This region is characterized by descending air currents and cloudless skies. At the earth's surface the winds are light and variable. The weather is generally fine; air humidity is comparatively low. This is in marked contrast to weather in the doldrums. It was from the persistent fine weather that the horse latitudes were so named, because horses had to be thrown overboard from sailing ships when lack of rain, combined with slow sailing in the light winds, caused water supplies to run low.

23.10. The Trade Winds. With surface pressure conditions high at the horse latitudes and low in the doldrums we would expect to find wind blowing from the high- to the low-pressure region. This is precisely what happens. The trade winds blow from the horse latitudes to the doldrums and are the most persistent in direction and force of any wind belt in the world. Captains of early sailing vessels, particularly Christopher Columbus, learned to take advantage of the trade winds on their voyages to the New World. Were it not for the rotation of the earth, the trade winds would blow directly from north to south. The deflective effect, however, turns them to the right so that they become the northeast trade winds. The trade wind belt shifts slightly in a north and south direction with the seasons. Off the northwest coast of Africa and the west coasts of Mexico and Central America the trades blow from a more northerly rather than northeasterly direction. The trades are not as well developed or as dependable in the southwest Pacific as in other oceans.

23.11. The Prevailing Westerlies. Surface air also flows northward from the high-pressure region of the horse latitudes. The Coriolis effect deflects it to the right so that it becomes a southwesterly wind. The prevailing southwesterlies of the temperate zone, or middle latitudes are not nearly so consistent as the trades of lower latitudes. This is because the region of the prevailing westerlies includes the paths of many storms throughout the year; these storms are associated with winds, from all points of the compass. Only occasionally are the trades interrupted by storms, the hurricanes which occur only during a portion of the year.

23.12. The Polar Cap of High-Pressure, and Prevailing Northeasterlies. Wind at the higher levels of the atmosphere flows poleward where it descends and tends to build up a region of high pressure at the earth's surface. Winds at surface levels therefore tend to blow southward but are deflected toward the right by the Coriolis effect and become the prevailing northeasterlies of the polar regions. We now note a situation where the surface polar northeasterlies eventually encounter the southwesterlies of the temperate zone.

23.13. The Polar Front. The air masses of the converging polar northeasterlies and the southwesterlies of the middle latitudes do not readily mix. Instead, the cold northern air tends to underrun the lighter and warmer air from the south. The surface between these two currents is known as the *polar front.* The average position of this frontal surface is at about latitude north 60 degrees. It is important however to realize that the polar front shifts to

positions which may vary from latitudes as far south as Florida to areas considerably north of the 60th parallel. For the most part the storms of the temperate zones have their origin along the so-called polar front, as we shall see in Chapter 26.

23.14. The Southern Hemisphere. Air in horizontal motion in the southern hemisphere is deflected toward the left. The trades south of the equator blow from the southeast rather than from the northeast; the prevailing westerlies are from the northwest rather than from the southwest. Wind from the cap of high pressure of southern polar regions blows from the southeast instead of the northeast, as in the northern hemisphere. The northern hemisphere contains extensive land areas, whereas the southern hemisphere is predominantly a water surface. Without the complicating effects caused by large land masses, the prevailing winds of the southern hemisphere are much more constant in direction than is the case in the northern hemisphere. Also wind speeds of the southern hemisphere average higher than is the case north of the equator, because of the reduced friction effect over water. The prevailing westerlies of the temperate zone of the southern hemisphere are known as the *Roaring Forties* because of their comparatively high velocities in the general area between latitudes south 40 and 50 degrees.

23.15. The Jet Stream. The jet stream was discovered toward the end of World War II, when American bombers flying to Japan encountered headwinds which often caused them almost to stand still with relation to the ground. Studies since then, along with reports from high-level flights, have established the fact that the winds in the upper troposphere of each hemisphere are normally concentrated into relatively narrow bands of strong winds called jet streams. These are centered just below the tropopause (30,000–60,000 feet) in mid-latitudes, but both latitudinal position and height vary considerably. The jet streams resemble rapidly-flowing, meandering rivers, flowing between banks of stagnant air. The average wind direction in jets is from west to east, but an individual jet will usually show north-to-south wave patterns, often of large amplitude. Wind speeds of up to 300 knots have been measured in jet streams, but the speed is more often in the 100–150 knot range. These jet streams play an important role in the development and movement of surface storms, and they are associated with clear air turbulence.

23.16. Heating and Cooling of Land and Water. The general pattern of global wind circulation at the earth's surface is considerably modified by the uneven heating of the continents and oceans. During the daytime, land areas are usually much warmer than they are at night. This is because the heat which is absorbed during the day penetrates only a short distance and is readily reradiated to open space. The balance between incoming and outgoing heat occurs at about two hours past noon. After that time land areas lose heat by radiation faster than they receive heat from the sun. Likewise there is a considerable annual variation in land temperatures; they are much colder during winter than in summer.

The effect of the sun's heat upon ocean surfaces is much different from that on land because of the heating qualities of water. Water is a good absorber because the heat can be mixed mechanically through a thicker layer than land, which must rely upon slower molecular processes. Water is a good radiator, so is effective in heating the atmosphere. Water has a heat capacity two or three times that of land, so can absorb great amounts of heat without heating to the high daytime ground temperatures of a desert and, conversely, it can give up comparable amounts without getting cold. Water evaporates continuously from the oceans, a heat loss which keeps oceans from getting too warm in summer.

23.17. Permanent and Semipermanent High and Low Centers. In winter the continental land masses of North America, Asia, and Europe are much colder than the waters of the north Atlantic and Pacific oceans (Fig. 23.12). The result of this is the building up of high-pressure areas over the continents and low-pressure centers over the adjacent oceans. The *low* which lies between Canada and the Scandinavian peninsula is known as the *Icelandic low*. The counterpart low area in the Pacific is known as the *Aleutian low*. These low areas are associated with much cloudiness, rain, drizzle, sleet, snow, fogginess, and strong winds. The stormy weather of these regions is not unlike stormy weather of any other section, but it is more widespread, persistent, and intense.

It must be borne in mind that the Aleutian and Icelandic lows do not represent a continuation of one and the same low-pressure area. Rather, they are regions where low-pressure systems form or arrive from other places to remain for a time. Later the lows may move on or die out and are replaced by other lows. The Aleutian and Icelandic centers shift to various positions and are at times replaced by high-pressure areas.

Semipermanent high-pressure areas in the northern hemisphere are located in the Atlantic near the Azores and in the Pacific off the coast of California. A lesser center is found in the vicinity of Bermuda. In the southern hemisphere semipermanent high centers are located in the Pacific west of Chile, the Atlantic west of Africa, and the Indian Ocean. These high centers represent intensifications of the ring of high pressure which lies between the trades and the prevailing westerlies in both the northern and southern hemispheres.

The semipermanent lows and highs affect the general scheme of global wind circulation and have a decided effect on the weather in many parts of the world. They also have a direct relation to the direction and velocity of the currents of the oceans. Having considered the general pattern of world wind circulation, pressure, and heat distribution, we will now look at the seasonal winds.

23.18. The Monsoon Winds. Monsoon winds develop in response to the annual variation in temperature between continents and oceans. These differences in temperature and therefore in pressure cause semiannual reversals in the wind direction in the areas affected. The results are quite marked in the Indian Ocean, China Sea, and south and southeastern Asia (Figs. 23.14 and

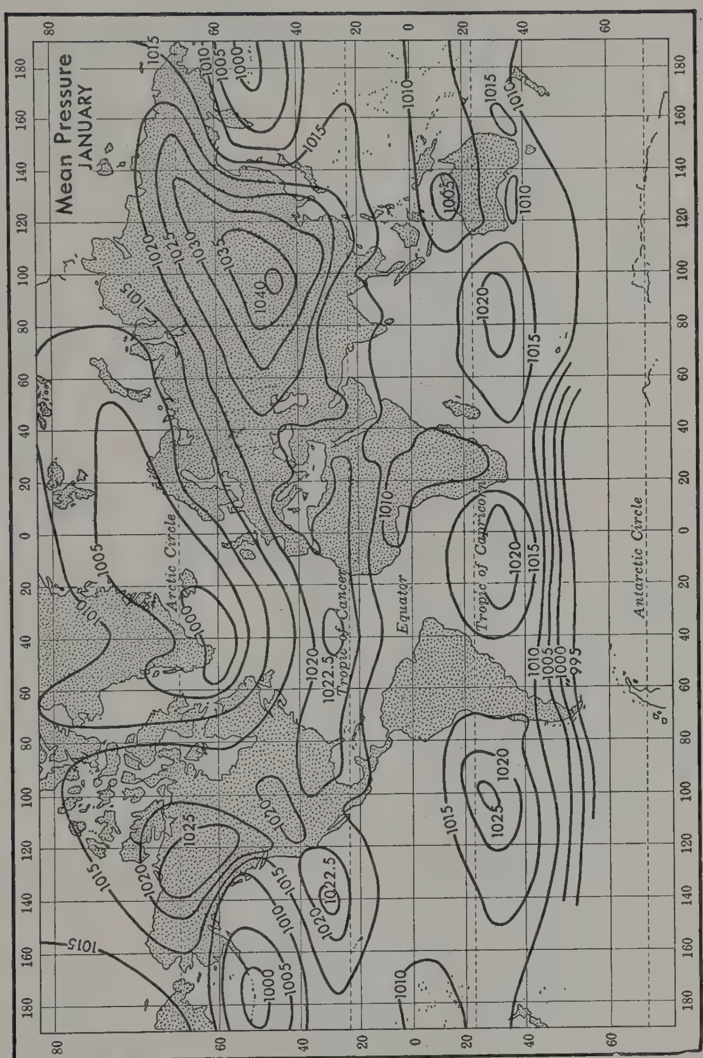


FIG. 23.12 ISOBARS OF MEAN PRESSURE FOR JANUARY

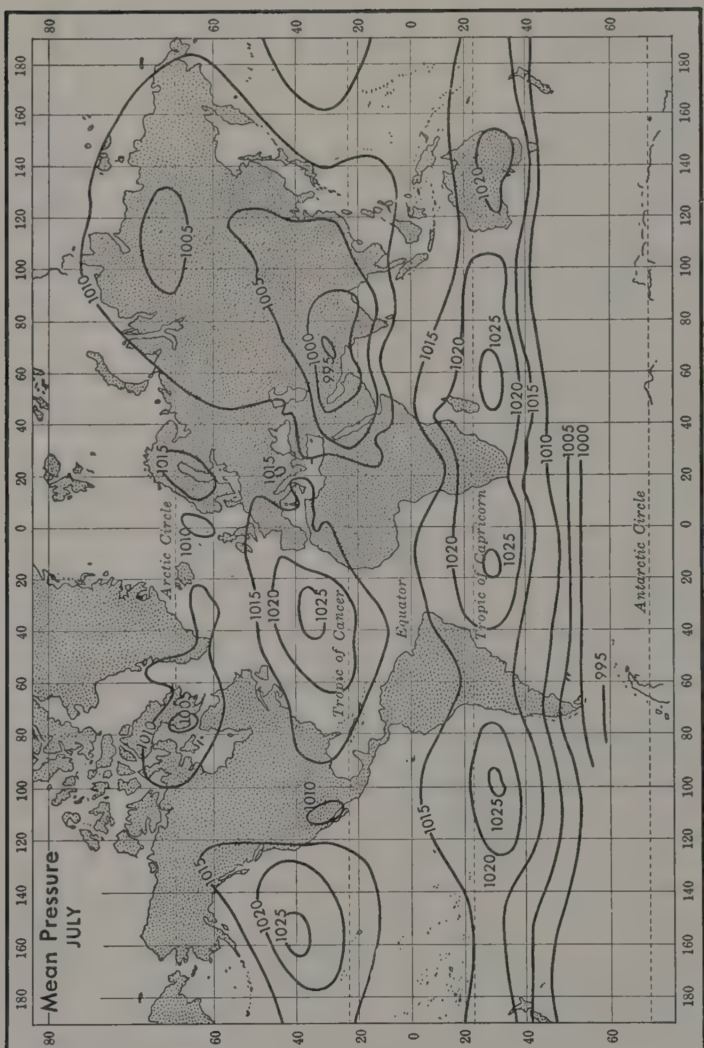


FIG. 23.13 ISOBARS OF MEAN PRESSURE FOR JULY

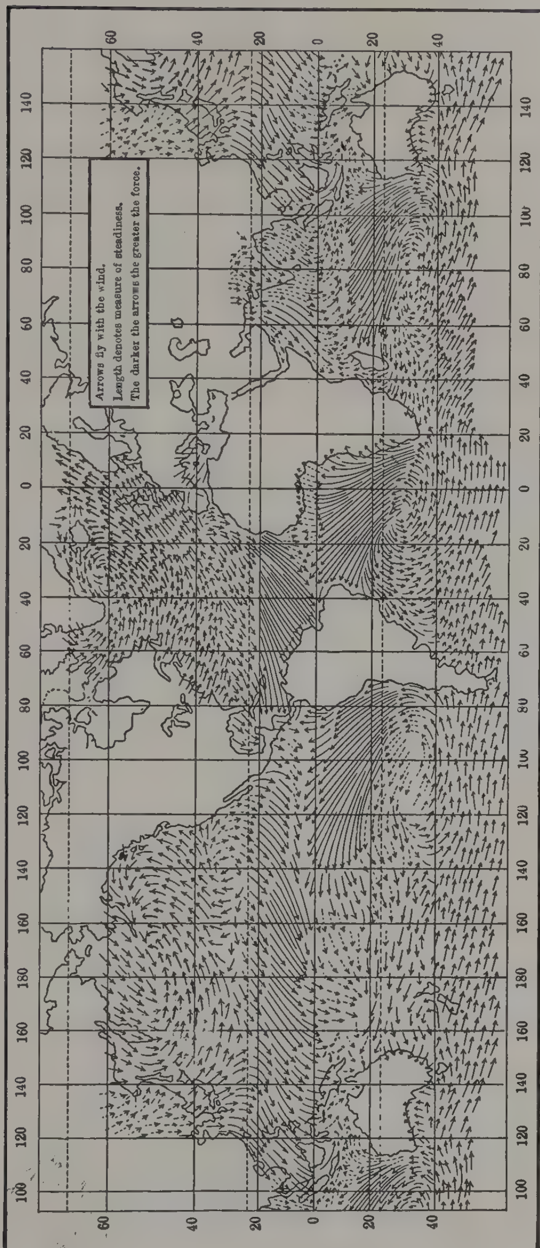


FIG. 23.14 OCEAN WINDS, JANUARY AND FEBRUARY. *Courtesy U.S. Weather Bureau*

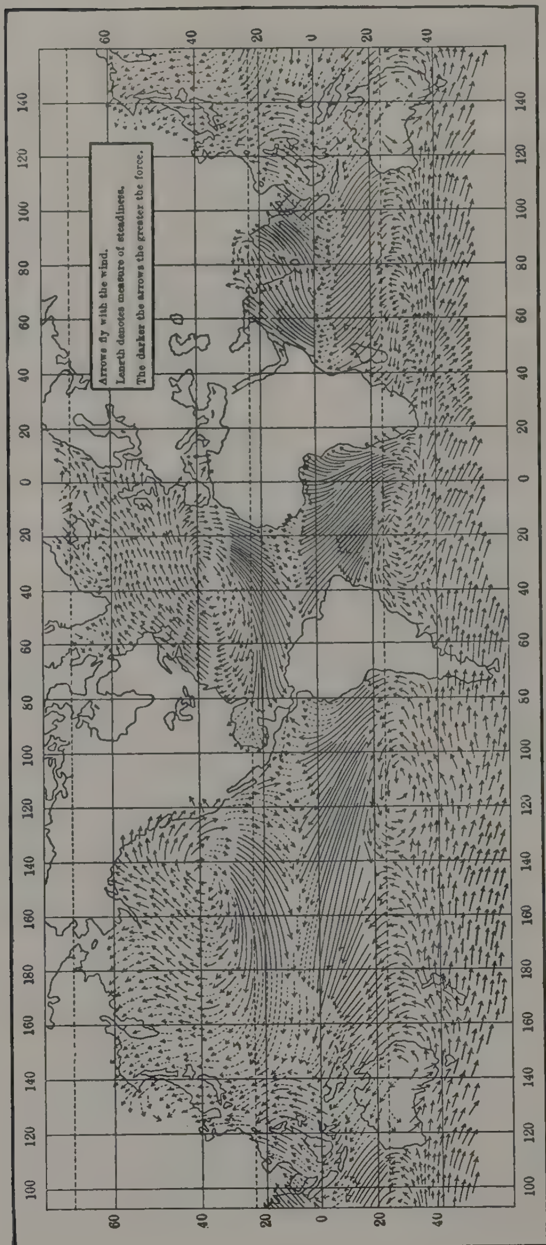


FIG. 23.15 OCEAN WINDS, JULY AND AUGUST. *Courtesy U.S. Weather Bureau*

23.15). During the winter season air flows outward from the interior of the continent of Asia toward the regions of lower pressure which prevail over the warm waters of the Indian Ocean and Australia. In India and southeastern Asia the winds then prevail from the northeast and are dry because of their origin and their descent on the southern slopes of the east-west Himalaya range; it is the season of fine weather in that part of the world and extends from October to April. After the winds cross the equator, they are deflected toward the left and become northwest winds.

During the warmer portion of the year conditions are reversed. The southeast trades south of the equator cross to the northern hemisphere and are then deflected toward the northeast, becoming the winds of the southwest monsoon of south and southeast Asia. It is then that the wind flows from the relatively high-pressure area of Australia and the Indian Ocean to the area of low pressure which prevails over the continent of Asia. As the moist ocean winds reverse themselves and move inland over India and adjacent sections, they bring heavy squalls, rains, and occasional cyclones (like Atlantic hurricanes). The summer monsoon usually occurs from May to September. During this season there is considerable local variation in winds and rain, but, in general, it is the rainy season for that part of the world. In areas where the winds are deflected for considerable distances upward by the Himalayas, very heavy rainfall is reported. Cherrapunji, India, has an average annual rainfall of 35½ feet, and most of it comes during the summer monsoon.

Many other parts of the world have similar seasonal reversals in wind direction which are often associated with dry and rainy seasons. A mild monsoon wind reversal is noted in the states bordering the Gulf of Mexico, and there are monsoon-type winds in Australia, Central and South Africa, and in South America.

23.19. Land and Sea Breezes. In the tropics and particularly during the warmer seasons of higher latitudes, the land during the day is commonly warmer than adjacent water. This applies not only to coastal sections but to inland lakes as well. Air overlying the land is heated, it expands, and is pushed upward by cooler air which flows onshore from the surface of adjacent water. Such sea breezes may penetrate inland for distances of 25 miles or more, although they extend only a few hundred feet above the ground. On inland lakes the effect usually prevails for distances of only a few miles. Over land surfaces at night, loss of heat by radiation causes. Land surfaces to become cooler than water surfaces, and a reversal of the wind direction takes place. The contrast between land and water temperatures at night is not as great as during the day; therefore the nighttime land breeze is usually not as strong as the sea breezes of daytime.

23.20. Mountain and Valley Breezes. During the daytime convectional currents tend to rise over mountains because of heating of mountainsides and summits. A general flow of air takes place up the valleys. At night radiation brings about chilling of the mountain slopes with the resultant chilling of the

adjacent air. The cool, dense air then drains down the valleys. Winds of quite high velocity are sometimes noted, particularly in narrow canyons.

23.21. Gravity or Drainage Winds. During the cold season, strong high-pressure areas of dense, cold air build up over plateaus and inland areas sheltered by mountains. Usually, the air will seep down the slopes and come to the coast as a gentle or moderate breeze. But an approaching low-pressure center may cause the cold air to be accelerated through the mountain gaps and valleys to arrive at the coast with strong, gusty winds. The effect is most pronounced when the cold air must pass through a narrow valley, or through an opening where several valleys converge. The *Santa Ana,* of Southern California, is the most common example of destructive gravity winds in the United States. The most widely known wind of this type is the *bora,* a cold, north-northeasterly wind which blows over the northern shores of the Adriatic. Winds over 80 mph, with gusts to 135, have been recorded in *boras.* Other well known gravity winds are the *mistral* of southern France, *Northers* in the Gulf of Mexico, *Tehuantepecers* and *Papagayoes* on the west coast of Mexico and Central America.

24

Clouds, Thunderstorms, Stability, and Fog

24.1. Introduction. A knowledge of the various kinds of clouds, how they form, and what they mean is an indispensable tool to those at sea, in the air, or to anyone who must deal with the weather and its changing conditions. Because clouds offer visual evidence of conditions which exist in the atmosphere and of changes which are taking place, they also afford an indication of coming weather conditions, particularly if they are observed at intervals to note changes in structure or type which may be taking place. For example, one of the first indications of the existence of an approaching midlatitude or tropical cyclone is the appearance of cirrus clouds. As the storm moves closer, cirrostratus, then altostratus clouds are noted. Finally, with the storm at hand, low, dark clouds are present.

Aviators soon learn to know the clouds which are associated with rough air and smooth air and the kinds which cause their planes to be coated with ice.

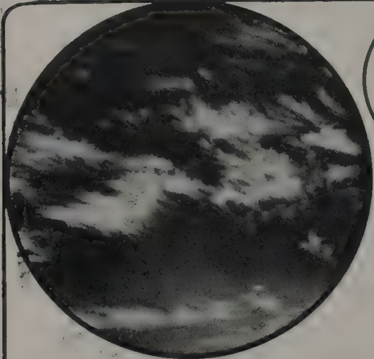
Clouds, as seen from the earth's surface, are divided into three groups according to structure and height. *Cirrus* clouds, of the high family, are feathery and silky-like; *stratus* are the layer clouds which form a more or less uniform flat mass over most or all of the sky; *cumulus* are the heap-shaped, lumpy masses. In height above ground, *cirrus* clouds occur only in the upper troposphere; *stratus* are only at low levels, while certain stratiform clouds are present only in the middle troposphere. *Cumulus* clouds may extend from near the ground to the *cirrus* level.

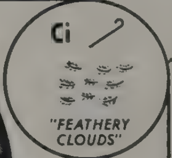
The principal types of clouds are grouped by height as follows: *Cirrus, cirrostratus, cirrocumulus*—20,000 to 40,000 feet; *altostratus, altocumulus*—8000 to 20,000 feet; *stratus, stratocumulus, nimbostratus*—below 8000 feet. Except for the low-cloud genera, the others tend to be higher in the tropics than at higher latitudes.

Cloud forms are divided into ten genera. In addition, there are many subtypes and combinations, but these need not be discussed here. The International Cloud Atlas, published by the World Meteorological Organization, contains detailed descriptions and excellent photographs of all cloud forms.

24.2. Specific Descriptions of the Ten Genera. *Cirrus* are detached clouds of delicate and fibrous (hair-like) appearance, without shading, generally

The symbols shown below are used by weather men all over the world. The cloud pictures used here are

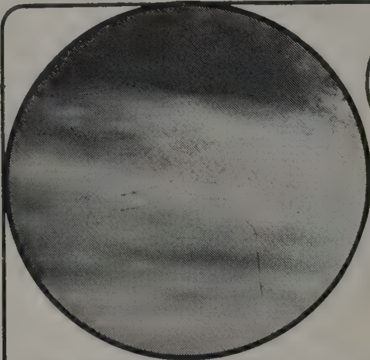


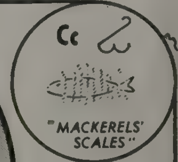


Often seen during fair weather.

At times serve as first visible indication of approaching storm.

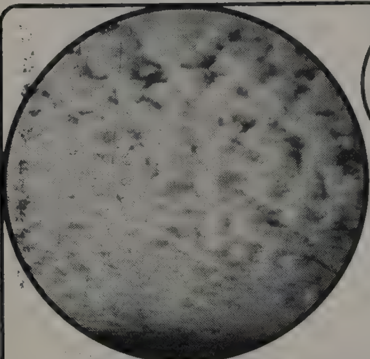
CIRRUS clouds are observed at very great altitudes and owe their fibrous and feathery appearance to the fact that they are composed entirely of ice crystals. Although the word "cirrus" derives from the Latin for "curl" or "lock," the clouds are found in varied forms including curved wisps, featherlike plumes, isolated tufts, and thin lines. Because of their height, they color before other clouds at sunrise and remain lighted after sunset.

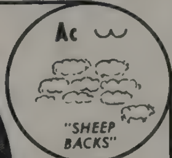




Look for wind and rain if they change to cirrostratus and lower thicker clouds.

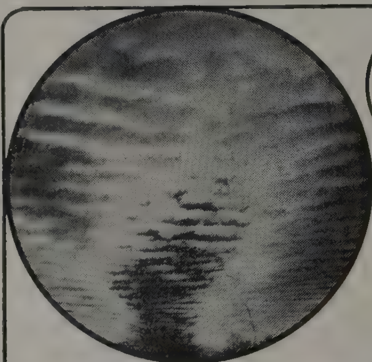
CIRROCUMULUS are similar to cirrus clouds but contain globular cotton-like masses arranged in groups or lines which at times give them the appearance of rippled sand on the seashore. One form of cirrocumulus is commonly known as the "mackerel sky" because of the way in which the pattern resembles the scales on the back of a mackerel. The harder and grayer variety, often indicate foul weather may follow.

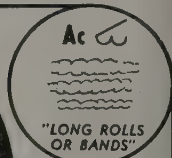




If this formation precedes lower cumulus clouds look for thundery weather.

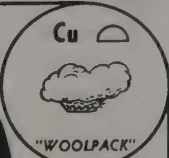
ALTOCUMULUS clouds (known as "sheep backs") are a layer of large, ball-like masses often so close together that the edges touch. They are often mistaken for an unbroken layer of stratocumulus. While the balls or patches may vary in thickness and color—from dazzling white to dark gray—they are more or less regularly arranged and distinct. They differ from cirrocumulus cloudlets in that they show distinct shadowed portions.





These rolls stretch to the horizon and move at right angles to their length.

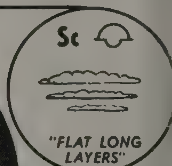
ALTOCUMULUS—in "bands" or "long rolls"—are shown above. This is a form of this cloud type having big roll clouds separated by streaks of blue sky. The rolls appear to be joined together near the horizon because of the effect of perspective. These regular parallel bands of altocumulus differ from the "mackerel sky" in that it is found in larger masses with shadows and is not composed of ice crystals like the higher cirrus forms.



This type generally seen in fine weather.

Turbulence increases as thickness increases.

CUMULUS clouds pictured above are the small, fluffy, "fair weather type." *The various types of clouds in the cumulus family are defined according to the extent of their vertical development—the height to which warm moist air is being raised by updrafts within them.* It is the presence of these updrafts which makes flying near or in cumulus clouds "bumpy" and sometimes dangerous. Note little vertical development.



Tail-end of the day's cumulus clouds.

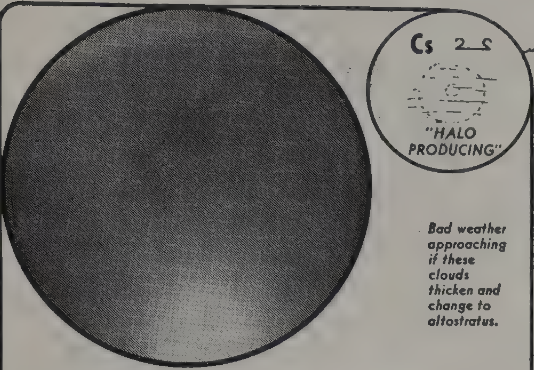
Usually a clear night ahead over land.

STRATOCUMULUS clouds shown above are the final product of daily changes in cumulus clouds. They vary greatly in altitude. At lower levels this type also appears as roll-shaped masses which are soft and gray and can be composed of long parallel rolls. (Such rolls are good indicators of wind direction at their level because they form on crests of atmospheric waves at approximate right angles to the wind producing them.)

FIG. 24.1 CLOUD CHART. Courtesy All Hands *Magazine*

SHOULD KNOW ABOUT CLOUDS

the most frequent types observed but there are specific cloud types for each of the code symbols shown.

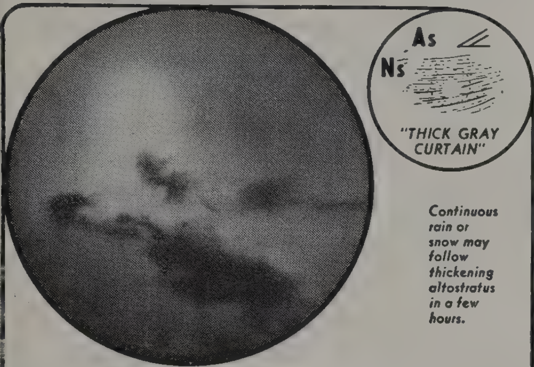


Bad weather approaching if these clouds thicken and change to altostratus.

CIRROSTRATUS covers the sky with a thin whitish veil. The cloud layer is not sufficiently dense to obscure or blur the outlines of the sun or moon. However, the ice crystals of which the cloud is composed, refract the light which passes through them in such a way that a ring known as a "halo" forms around the sun or moon. Cirrostratus clouds which follow after cirrus may be an indication of approach of low-pressure area.

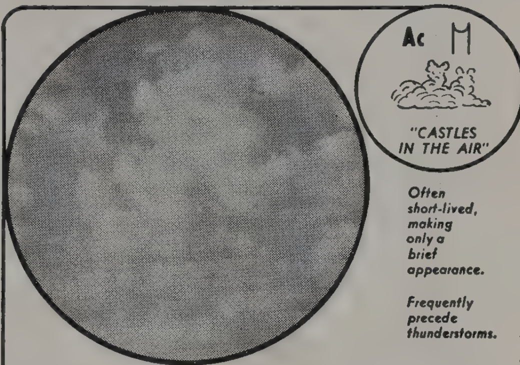
This type appearing after cirrus and followed by thickening lower clouds, increases probability of rain within 24 hrs.

CIRRUS and cirrostratus. "Mare's tails" is the popular name given to well-defined cirrus clouds that thicken into cirrostratus, and then gradually lowering into water droplet altostratus. The clouds may resemble a mare's tail and may often be the forerunner of a storm as indicated in the old rhyme: "Mackerel sky and *mare's tails*, make tall ships carry low sails." The more brush-like the cirrus, the stronger the wind at that level.



Continuous rain or snow may follow thickening altostratus in a few hours.

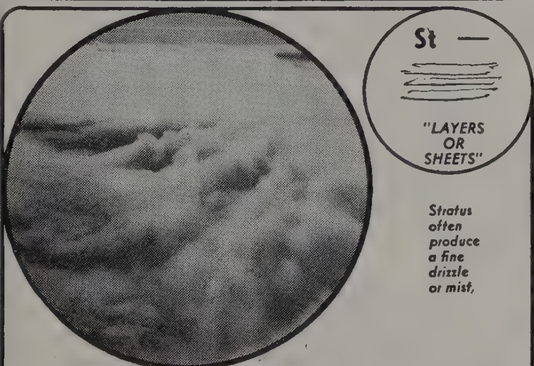
ALTOSTRATUS clouds have the appearance of a gray or bluish, fibrous veil or sheet which is sufficiently dense so that the sun and moon generally appear as they would through ground glass. There is no "halo" as usually seen through cirrostratus but a similar phenomena called a "corona" may be observed. The low ragged "scud" or NIMBOSTRATUS "rain clouds" that form under altostratus clouds grow denser and lower as rain falls.



Often short-lived, making only a brief appearance.

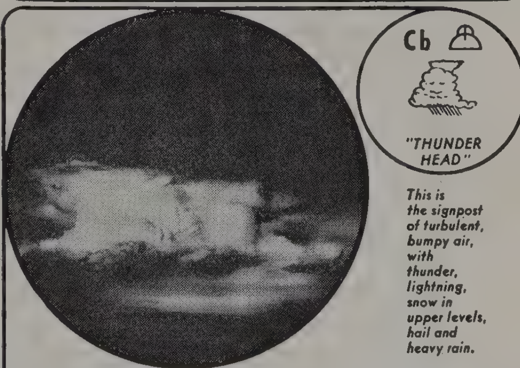
Frequently precede thunderstorms.

ALTOCUMULUS. These "castles in the air" are visible proof of the great altitude to which rising currents in the atmosphere often extend. Generally arranged in a line and resting on one horizontal base, they give the impression of turrets on a castle. These turreted tops look like miniature cumulus clouds and possess considerable depth as well great length. These clouds usually indicate a change to chaotic, and thundery skies.



Stratus often produce a fine drizzle or mist,

STRATUS formations are low horizontal, uniform layers of clouds. Strong winds sometimes break them up into irregular fragments or shreds called FRACTOSTRATUS. A veil of true stratus gives the sky a hazy appearance. Because of their thickness, stratus appear dark to sailors and landsmen, but look white to aviators. Clouds of stratus family are called "low stratus" if their base is below 1,000 ft. and "fog" when on the ground.



This is the signpost of turbulent, bumpy air, with thunder, lightning, snow in upper levels, hail and heavy rain.

CUMULONIMBUS "thunderheads" or "showerclouds" are heavy masses of clouds rising in mountainous towers to great heights. The upper parts consist of ice crystals and often spread out in the shape of an anvil. The base is horizontal, but as showers occur it lowers and becomes ragged. The anvil of this giant cloud is so high that it can be seen many miles away long before the base becomes visible. A regular "cloud factory."

FIG. 24.1 (Cont.)

white in color, and often of a silky look. *Cirrus* clouds appear in a variety of forms, such as isolated tufts, lines drawn across a blue sky, branching feather-like plumes, curved lines ending in tufts, etc. They are often arranged in bands which cross the sky like meridian lines and, owing to the effect of perspective, converge to a point on the horizon.

Cirrocumulus is a thin, white patch, sheet, or layer of cloud without shading, composed of small, white flakes or of very small globular masses, usually without shadows, which are arranged in groups or lines, or more often in ripples resembling those of the sand on the seashore. In a uniform arrangement, these clouds form what sailors used to call "mackerel sky."

Cirrostratus is a transparent, whitish cloud which generally produces halos. It never obscures the sun to the extent that shadows are not cast by objects on the ground. Sometimes it is quite diffuse and merely gives the sky a milky look; sometimes it more or less distinctly shows a fibrous structure with disordered filaments.

Altocumulus is a layer (or patches) composed of laminae or rather flattened globular masses, the smallest elements of the regularly arranged layer being fairly small and thin, with or without shading. These elements are arranged in groups, in lines, or waves, following one or two directions, and are sometimes so close together that their edges join. The thin and translucent edges of the elements often show variations in coloring which are characteristic of this class of cloud. *Altocumulus* clouds do not produce halos.

Altostratus is a striated or fibrous veil more or less gray or bluish in color. This cloud is like thick cirrostratus but without halo phenomena; the sun or moon shows vaguely with a faint gleam as though through ground glass. Sometimes the sheet is thin with forms intermediate with *cirrostratus.* At times it is very thick and dark, even completely hiding the sun or moon. In this case differences of thickness may cause relatively light patches between very dark parts; but the surface never shows real relief, and the striated or fibrous structure is always seen in places in the body of the cloud. Every form is observed between high *altostratus* and *cirrostratus* on the one hand, and low *altostratus* and *nimbostratus* on the other. Rain or snow commonly fall from *altostratus.*

Stratocumulus is a layer (or patches) composed of laminae, globular masses, or rolls; the smallest of the regularly arranged elements are fairly large; they are soft and gray with darker parts. These elements are arranged in groups, in lines, or waves, aligned in one or two directions. Very often the rolls are so close that their edges join; and when they cover the whole sky, they have a wavy appearance.

Stratus is a low, generally gray cloud layer, with uniform base and top. It has the same characteristics as fog, but does not occur on the ground. When the sun can be seen, its outline is clearly discernible. Mariners often refer to *stratus* as scud.

Nimbostratus is a low, amorphous, and rainy layer of a dark gray color usually nearly uniform; it is feebly illuminated, seemingly from inside. When

it gives precipitation, it is in the form of continuous rain or snow. But precipitation alone is not sufficient to distinguish the cloud which should be called *nimbostratus* even when no rain or snow falls from it. There is often precipitation which does not reach the ground; in this case the base of the cloud is usually diffuse and looks wet on account of the general trailing precipitation, and it is not possible to determine the limit of its lower surface.

Cumulus are dense clouds with vertical development; the upper surface, dome-shaped and exhibiting rounded protuberances, resembles a cauliflower, whereas the base is nearly horizontal. When the light comes from the side, the clouds exhibit strong contrasts of light and shade; against the sun, on the other hand, they look dark with a bright edge. True *cumulus* is definitely limited above and below, and the surface often appears hard and clear-cut. But one may also observe a cloud resembling ragged *cumulus* in which the different parts show constant change; this cloud is designated *fractocumulus*.

Cumulonimbus are heavy masses of cloud with great vertical development whose cumuliform summits rise in the form of mountains or towers and whose upper parts have a fibrous texture, often spreading out in the shape of an anvil. The base resembles *nimbostratus*, and often has a layer of very low, ragged clouds below it (*fractostratus, fractocumulus*). *Cumulonimbus* clouds generally produce showers of rain or snow and sometimes of hail and often thunderstorms. If the whole of the cloud cannot be seen, the fall of a heavy shower is enough to characterize the cloud as *cumulonimbus*.

24.3. What Do Clouds Mean? Cloud types, by themselves, are significant only if consideration is given to the method and timing of their development, the structural changes that are taking place, and particularly to the sequence in which they occur.

Cirrus clouds are usually the first sign of an approaching storm, but to have detection significance, they must increase in number and be succeeded by cirrostratus clouds. Cirrostratus, if a storm is approaching, must thicken and be succeeded by altostratus. Altostratus clouds are succeeded by nimbostratus and the precipitation which started with the altostratus continues—often with fog present. Stormy conditions are present with both altostratus and nimbostratus. The end of these conditions is signalled by breaks in the low clouds and patches of blue sky to the west. Storms in mid-latitudes generally move from west to east, so their approach is indicated by clouds from the west, their retreat by clearing conditions in the west.

Cumulus clouds mark the tops of rising air currents, caused by horizontal temperature differences at the earth's surface. Air may also be started upward when deflected by a hill or mountain or by encounter with a colder and denser air mass. Whether or not an air current continues to ascend depends upon its temperature as compared with the temperature of the surrounding air.

If cumulus clouds form early on a summer morning, it means that the air is quite moist and convection has begun. This means that the clouds are likely to become more numerous by afternoon, build up to high levels, and by the

middle of the afternoon thunderstorms are likely. If cumulus clouds do not appear until late in the morning, it means that the air has little water vapor because convection currents had to reach high levels before the air became saturated. The afternoon would have comparatively few clouds; the bases of these would be high, but their tops would not reach to the great heights of cumulonimbus clouds.

In the late afternoon if the air is stable, the afternoon cumulus clouds will gradually disappear, and by evening the sky will be clear. If the air, however, is unstable, the clouds will continue to build up to great heights even during the evening, and thunderstorms are likely then even at night.

An examination of the weather and operational significance of the ten principal cloud types will now be made.

Cirrus clouds arranged in filaments or strands, scattered and not increasing (Mares' Tails), have no meaning as related to weather, except to signify that any bad weather is far distant. Cirrus in thick patches, often anvil shaped, mean that showery weather is near. These clouds are associated with and formed from the tops of thunderstorms. Cirrus clouds shaped like hooks or commas signal the approach of a warm front, almost certainly if followed by cirrostratus clouds. Also, they indicate the presence and location of jet streams. None of the cirrus types have significance for flight operation except for what use may be made of the jet stream identification.

Cirrostratus clouds, when in a continuous sheet and increasing, signify the approach of a warm or occluded front with attendant rain, snow, and stormy conditions. If the clouds are not continuous and increasing, it signifies that a storm is passing to the south of the observer and no bad weather will occur. Other than reduced visibility within the clouds, cirrostratus have no flight significance.

Cirrocumulus clouds are rare, and are of mixed significance. In some areas they foretell good weather; in others, bad. Good weather areas are England, New England, and along the west coast of the United States. Bad weather areas are southern Europe, particularly Italy. These clouds have no significance in the tropics. They have no flight operational significance except that they are somewhat more turbulent than cirrus and cirrostratus.

Altostratus clouds are the most reliable weather indicator among the cloud family, and the greatest help to the single-station forecaster. They nearly always indicate frontal overrunning, and impending rain or snow of the steady all-day type, if the overcast cloud layer progresses continually over a station and thickens. Another important aid given by altostratus clouds is the detection of new storm development, particularly at sea where reports are few. Altostratus clouds will often signal formation of a low long before it is apparent from the surface-level isobars or wind. Flight conditions in altostratus are usually not prohibitive. Turbulence is generally light, and icing is serious only if prolonged flight through the cloud is required. What is important to pilots and surface observers is the indication of approaching

rain and the warm front, with associated low ceilings, poor visibility, and possibly heavy icing in lower clouds.

Altocumulus clouds, in general, are indicative of instability at high levels, but are significant only when followed by thicker, high cloud forms or cumuliform lower clouds. When arranged in parallel bands, these clouds are found in advance of warm fronts, on the forward and lateral edges of altostratus sheets, and near the axis of the jet stream. North of this banded type, altostratus and precipitation may be expected, and if the altostratus is moving southward, precipitation may be expected at the given station. When altocumulus occurs in the form of turrets rising from a common flat base, it is frequently the forerunner of instability in a deep layer, with heavy showers and thunderstorms. For flight operations, altocumulus clouds are characterized by only mild turbulence, and only light to moderate icing. When associated with thunderstorms, of course, flight hazards increase markedly.

Stratocumulus clouds which form from degenerating cumulus clouds are usually followed by clearing at night and fair weather. The roll stratocumulus, with its washboard-looking undersurface, is characteristic of the cold seasons over both land and water, where the air is cooled from below and mixed by winds of 15 knots or more. This cloud yields no more than light precipitation of the drizzle type—possibly fine snow. Stratocumulus will persist for long periods under proper air-to-land or -sea temperature relations. Stratocumulus rarely presents serious flight hazards. It is thin, so a flight path can be chosen above or below the cloud layer. It does cause icing, which must be taken into account during take-offs and landings, or when operational situations require prolonged flight in the cloud layer. Also, visibility may be seriously reduced in the stratocumulus drizzle or snow.

Stratus clouds have little weather significance. They indicate an inversion at low levels, a few hundred feet above the surface. Other than light drizzle, no stratus precipitation can be anticipated except that from higher clouds when the stratus forms ahead of a warm front. In this case, the rain supersaturates the cold air, stratus, then fog, will form. On continental west coasts, such as California, the absence of stratus in summer is more significant than when it is present. It implies off-shore flow and higher maximum temperatures —80's and 90's instead of the usual 60's to 70's. Stratus clouds are a serious hazard to flight because of the low ceilings, but represent no hazard to surface operations.

Nimbostratus clouds are of little help as a forecasting device, since the bad weather is already at hand when these dark clouds with their heavy rain or snow are overhead. It can be assumed, once nimbostratus has formed, that existing wind and weather conditions will persist for several hours. For flight operations, nimbostratus offer hazard because of occasional heavy turbulence, low ceilings, and heavy icing. The stormy conditions which accompany nimbostratus clouds make surface operations difficult.

Cumulus clouds, when detached and with little vertical development, are

called "fair weather cumulus" and have practically no effect upon flight operations. When cumulus clouds swell and have considerable vertical development, with dome-shaped protuberances forming a cauliflower-like pattern at the top of the cloud, there are deep layers of instability. Shower and thunderstorm development is likely, but this can only be forecast with assurance through knowledge of the height of the freezing level and high-level inversions. This type of cumulus cloud is very turbulent, and above the freezing level, can cause the heaviest aircraft icing. However, since cumulus clouds usually cover only about 25 percent of the sky, they can be easily circumnavigated. They affect surface operations only by the gusty winds which occur in the showers.

Cumulonimbus clouds, which may extend from near the surface to as high as 65,000 feet, represent the greatest layer thickness of instability to be found in the atmosphere. The immediate implication of a cumulonimbus which has developed to the thunderstorm stage is heavy rain, lightning, gusty winds, and possibly hail. It is the most dangerous cloud for flight operations because turbulence may cause loss of control or structural damage.

24.4. How Clouds Form. Clouds result chiefly from ascending air currents. When air rises, it encounters regions of lower pressure, and expands. If not saturated with water vapor, expanding air cools at the rate of 5.5 degrees F for each 1000 feet of rise above the earth. If a current of air rises sufficiently high, its temperature will eventually decrease to a value at which the air will be saturated with water vapor. Any further temperature decrease will cause some of the water vapor to be condensed into cloud particles.

24.5. Adiabatic and Pseudo-Adiabatic Rates. The cooling rate of 5.5 degrees F per 1000 feet for rising and expanding unsaturated air is known as the adiabatic, or dry, rate of cooling. An adiabatic cooling process is one in which no heat is added or taken away from the mass of air by exchange with the environment; the air cools only because of expansion.

Should a volume of air grow colder than its surroundings, it contracts, becomes denser, and sinks in the atmosphere. Its descent is associated with compression and warming at the adiabatic, or dry, rate of 5.5 degrees F for each 1000 feet of fall in elevation. The dry adiabatic rate of warming or cooling of air applies only to air which is not saturated with water vapor, i.e., air which has a relative humidity of less than 100 percent.

If rising air, because of cooling to the dewpoint, becomes saturated with water vapor, it continues to expand, but its rate of cooling is only about one half the dry adiabatic rate. The reason for this is that in changing from the gaseous to liquid state, the vapor releases latent heat of condensation at the rate of about 2.8 degrees F per 1000 feet of height increase. Two processes, therefore, are in operation. The rising saturated air is cooling at the rate of 5.5 degrees F per 1000 feet and heating at the rate of about 2.8 degrees F. The net result is a cooling rate of about 2.7 degrees F for every 1000 feet of ascent. This rate is known as the wet adiabatic, or pseudo-adiabatic rate of cooling.

Descending air always heats at the dry adiabatic rate.

Foehn, or Chinook Winds. These winds illustrate the effects of the adiabatic heating and cooling of air. A foehn is a warm, dry wind which blows down the side of a mountain range. When atmospheric pressure conditions are higher on one side of a range than on the other side, air is caused to flow upward, over, and down the range toward the area of lower pressure on the leeward side. An example of these conditions is found in the Rockies when pressure is high over the north Pacific and low in the northern plains states. Fairly warm, moist air then flows inshore and ascends to higher ground. If at first the air is not saturated, it cools at the dry adiabatic rate of 5.5 degrees F for each 1000 feet rise in elevation. Once it becomes saturated, clouds form and the cooling rate decreases to about one half the dry adiabatic rate. Under these conditions rain or snow is very likely. Once the air reaches the region overlying the backbone of the Rocky Mountain range, it begins its descent at the dry adiabatic rate to the sections of eastern Montana and Wyoming, where it is known as a chinook wind and is much warmer and drier at any elevation than at a corresponding elevation on the western slope. This is, of course, due to the net cooling rate on the windward slope being less than the heating rate on the lee slope. The chinook wind is so pronounced at times that it has rapidly and completely melted and evaporated heavy blankets of snow east of the Rockies. Fig. 24.2 illustrates the formation of a chinook wind.

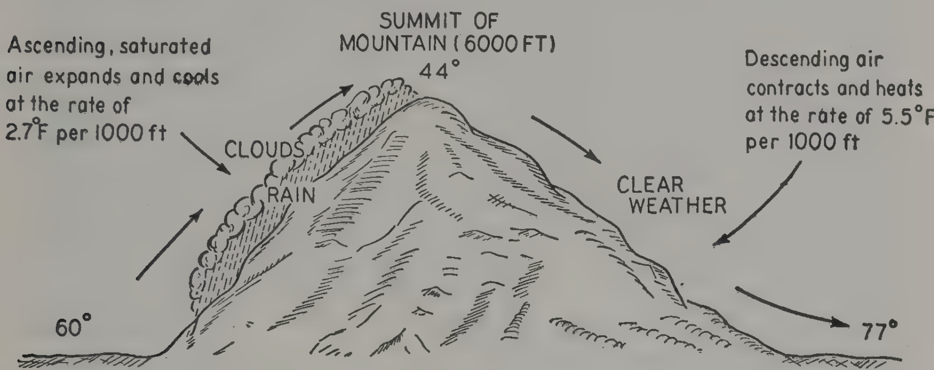


FIG. 24.2 THE FORMATION OF A CHINOOK WIND. Saturated air at a temperature of 60°F ascends a mountain range. Clouds and rain occur on the windward slopes. Upon reaching the summit the temperature of the air has decreased to 44°F. Descent on the leeward slopes results in the warming of the air so that its temperature is increased to 77°F, 17°F higher than at the corresponding level before ascent.

In Europe this type of wind is known as a *foehn.* It is common on the north slope of the Alps. Warm, moist winds from the Mediterranean are forced to ascend the southern slopes of the Alps when pressure is low over central Europe. As the wind descends to lower ground north of the Alps, it becomes the warm, dry *foehn.*

Four examples of cloud formation are as follows:

1. *Convection.* Consider the case of cumulus clouds which form over an island during the daytime. The land areas become warmer than the surrounding water surfaces. The warm land heats the overlying air and causes it to expand and become less dense. It is then pushed upward by cooler, denser air which flows inshore from the colder sea surfaces. If the rising air current continues to ascend, it will eventually cool to the dewpoint or temperature

FIG. 24.3 CUMULUS (Cu). *Official U.S. Navy Photograph*

where its water vapor causes saturation of the air. The relative humidity then is 100 percent, and any further rising and cooling of the air tend to result in the condensation of some of the water vapor into visible cloud particles. Cumulus clouds have flat bases. This is apparent if they are viewed from an airplane or in a diagonal direction from the earth. The flat base marks the elevation at which the rising air current cooled to the dewpoint. Typical cumulus clouds have rounded, domelike, clear-cut tops. Their tops (Fig. 24.3) mark the height of the ascending air currents which caused the clouds. At elevations below the cumulus cloud base the air was cooling at the dry adiabatic rate. Throughout the cloud mass the rising air column cools at the wet, or pseudo-adiabatic, rate. Cumulus clouds, once formed, may be carried horizontally for considerable distances by the winds, but without the support of rising currents they eventually tend to return to the invisible vapor form from which they had their genesis.

2. *Orographic Ascent of Air.* When the wind blows toward higher ground, such as a mountain range or barrier of hills, the air is forced upward. As it ascends, it expands and cools at the adiabatic rate. The cloud base forms at the height where the temperature of the rising and expanding air has decreased to the dewpoint. The tops of orographic-type clouds may extend to great heights above the terrain if the atmosphere is not stable. Stability is discussed later.

Regions of the world where prevailing moist winds are deflected upward by mountain ranges have heavy annual cloudiness and rainfall on the windward slopes. Sections to the leeward of mountains have much lower amounts of cloudiness and precipitation. India, lying south of the Himalaya range, records its heaviest rainfall during the portion of the year when the wind prevails from the south. In the winter when winds there prevail from north and are descending on the southern slope of the range, there is little cloudiness or rain.

3. *Overrunning Air Currents.* Now consider what happens when a current of cool air from the east converges with a current of warm air moving from the south. As you look at Fig. 24.4, note that you are facing west with north

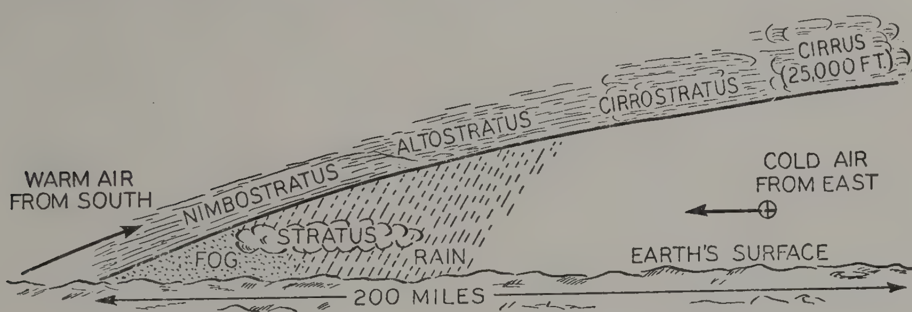


FIG. 24.4 A VERTICAL CROSS-SECTION THROUGH THE AIR LOOKING WEST. The cirrus clouds shown may be 25,000 feet above the earth's surface, and 200 miles north of the place where the warm current began its ascent over the cooler wedge of air.

to the right and south to the left. The current of cool air is moving away from you as indicated by the circle with a cross representing the tail of an arrow moving with the wind. The southern current is warmer and therefore lighter than the easterly current. When these currents meet, they do not tend to mix. The warmer current is deflected upward by the heavier, denser air as indicated in the figure. The figure actually shows what is known as a warm front. Fronts, together with air masses, are discussed in Chapter 26.

Many types of clouds are formed when an air current overruns another, rises, expands, and cools adiabatically. Four types—cirrus, cirrostratus, altostratus, and nimbostratus—are shown in Fig. 24.4.

4. *Turbulence.* Figure 24.5 shows how clouds may be formed because of turbulence. Wind blowing over the earth's surface, particularly over rough

terrain, causes upward and downward currents up to 1500 to 2000 feet above the surface and sometimes higher. Obviously if the air contains much water vapor, adiabatic cooling of the rising air currents may result in the air temperature reaching its dewpoint and the formation of clouds. The cloud types are either stratus or stratocumulus and are usually not rain-producing. The tops of these clouds ordinarily do not extend to elevations more than about 4000 feet above the ground. Turbulence due to surface friction does not often exist above this level. If the air is unstable, the tops may extend to any height.

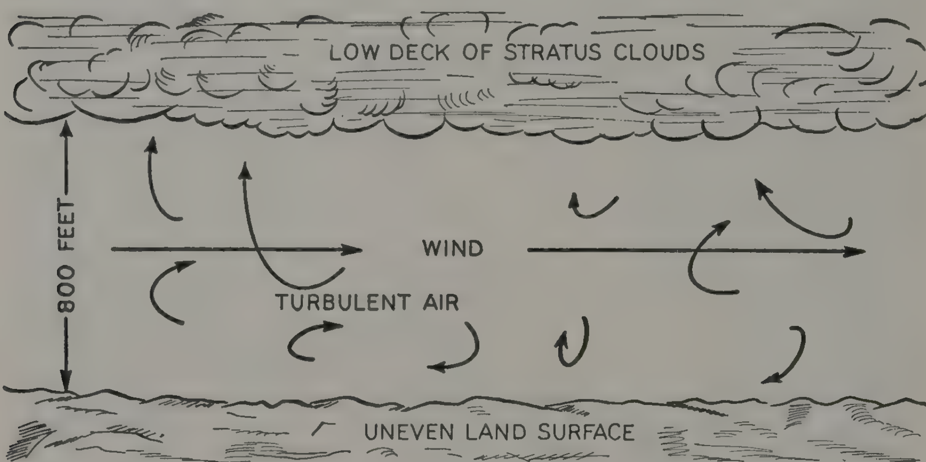


FIG. 24.5 STRATUS. These clouds may form when fresh to strong winds of high humidity blow over rough terrain. Friction with the ground surfaces causes upward air currents which expand, cool, and produce stratus or stratocumulus clouds.

The value of the wind velocity often determines whether clouds or fog will form. As we shall see later, gentle or light winds often produce fog when flowing over cold surfaces. If the wind velocity is moderate to strong, friction of air and ground so stirs up the air that clouds are more likely to form than fog.

24.6. Stability, Instability, and Conditional Instability: Inversions. Why are cumulus cloud tops low and rather flat on some days, whereas at other times the tops grow to great heights, sometimes building up to the great cumulonimbus cloud masses? The stability condition of the air is the answer to these questions, and the processes involved are as follows:

If a volume of air rises for any reason, as, for instance, in one of the ways described in the formation of clouds, it can do one of three things after the initial force which started it upward is removed. It may remain at the height to which it was forced; it may sink back to a lower level; or it may continue its journey upward. What it does depends on the stability of the air.

If the air is in a condition of neutral stability, the particle remains at the elevation to which it was pushed; if the air is stable, it will tend to drop back; but if the air is unstable, it will continue its journey upward.

It will be recalled from Chapter 23 that the temperature of the atmosphere on the average is 1 degree F colder at each 300 feet of elevation above the earth. This is only an average condition and is known as the lapse rate, or vertical temperature gradient. The existing lapse rate at any place and time may be either greater or less than 1 degree F per 300 feet. Sometimes the temperature is warmer at increased elevations; such a condition is known as an *inversion.*

Conditional instability is the term applied to air that is stable when cooling takes place at the adiabatic rate, but unstable when it occurs at the pseudo-adiabatic. Conditional instability is quite common and is the basis of much of our cloudiness and precipitation.

Figures 24.6, 24.7, and 24.8 graphically illustrate stable, unstable, and conditionally unstable conditions; flat cumulus and cumulonimbus clouds are shown on the appropriate diagrams. In Fig. 24.6 it will be noted that the

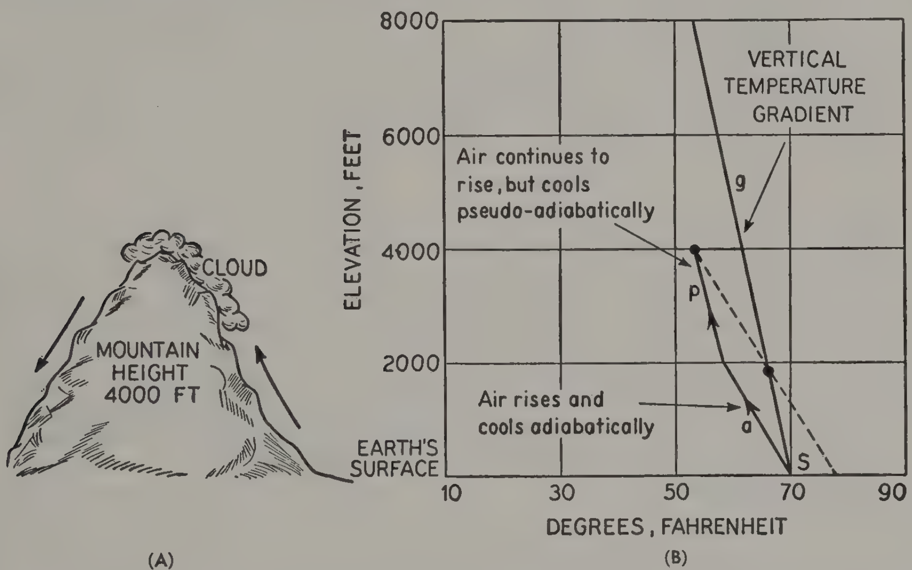


FIG. 24.6 STABILITY. (A) shows a current of air rising over a mountain. It expands and cools at the adiabatic rate (5.5°F/1,000 feet) until it reaches an elevation of 2,000 feet where the air becomes saturated. Rising from 2,000 to 4,000 feet it cools at the pseudo-adiabatic rate (about 2.7°F/1,000 feet). Now refer to graph (B). Let us assume that line g represents the existing vertical temperature gradient. Line a shows the rate of decrease in the temperature of the rising air current as it cools at the adiabatic rate. Line p shows the rate of decrease of the temperature of the rising air current as it cools at the pseudo-adiabatic rate. Looking back at (A) it will be noted that the mountain forces the air current only to a height of about 4,000 feet. Referring again to (B) it will be noted that at all heights the temperature of the rising column is less than its environment, and therefore stable. Hence upon reaching the leeward side of the mountain the air current will tend to descend.

cloud top does not extend to a great height because the air column which forms the cloud does not tend to continue upward beyond the level to which it is forced by the mountain. In Fig. 24.8 the cloud top reaches high because its air column continues to rise after being forced to 4000 feet by the mountain. In Fig. 24.7 any slight upward motion of the air at S will result in a rising

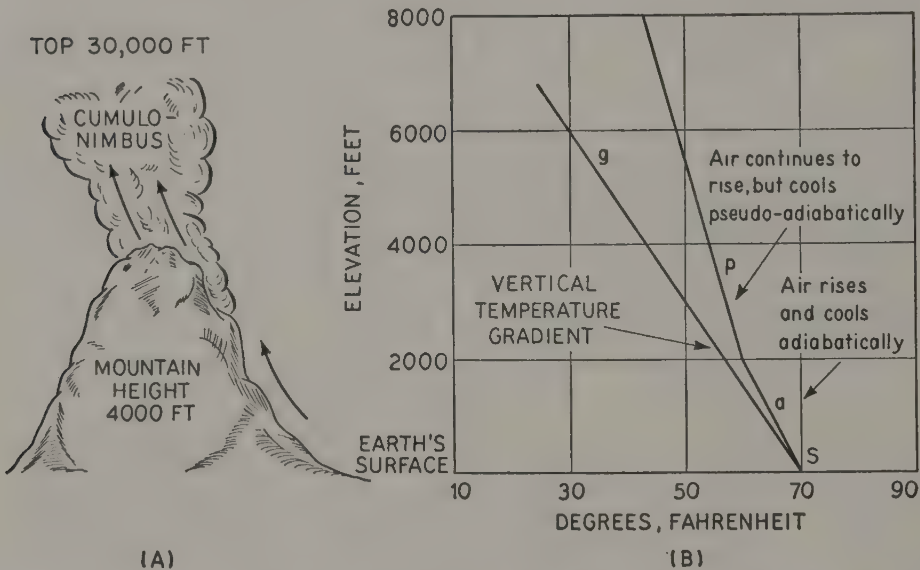


FIG. 24.7 INSTABILITY. Again, (A) shows a current of air moving from right to left and ascending a mountain slope. Expansion and cooling occur at the adiabatic rate up to 2,000 feet where the dewpoint is reached and a cloud base forms. Above 2,000 feet cooling takes place at the pseudo-adiabatic rate. Referring to (B) we note that the existing vertical temperature gradient is represented by line *g*. This temperature gradient is steeper than the one shown in Fig. 24.6. Lines *a* and *p* show the rate of temperature decrease while the air column is cooling at the adiabatic and pseudo-adiabatic rate, respectively. It will be noted that at any height the temperature of the rising air column (shown by line *a-p*) is greater than the air through which it is rising (shown by line *g*). Therefore, once the air begins to ascend the mountain slope it will tend to continue upward as long as it continues to be warmer than its environment.

air column; the column will continue to rise as long as it is warmer than its environment.

Figures 24.9A and B show low and high temperature inversions, respectively. Inversions at the earth's surface as in Fig. 24.9A, develop at night over land surfaces because of radiation of heat from the earth when skies are clear and winds are light. Ground fog is often the result. Inversions at levels above the earth's surface act as lids above which no air rising from below can penetrate. This condition causes a spreading out at the base of the upper air inversion of smoke and other restrictions to visibility.

Inversions near the earth's surface are important not only because of their relation to fog but also to air pollution, a problem which increases linearly with increasing population density. In areas like coastal Southern California, for example, there are persistent inversions which trap man-made pollutants. The topography, which allows for no low-level escape to the east, aggravates

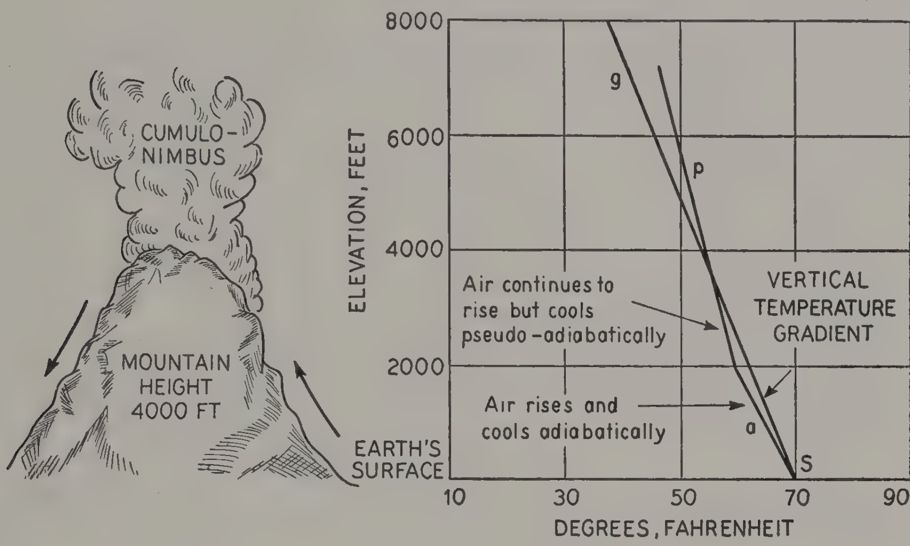


FIG. 24.8 CONDITIONAL INSTABILITY. Note that the existing vertical temperature gradient *g* is steeper than in 24.6, but not so steep as in 24.7. Air having this type of temperature gradient is stable for air columns rising and cooling at the pseudo-adiabatic rate. In this particular case air ascends the mountain slope from right to left. At 2,000 feet it has expanded and cooled to the dew-point where a cloud base forms. Between 2,000 and 4,000 feet the rising air column expands and cools at the pseudo-adiabatic rate. If the air column rises to just above 4,000 feet, it will be warmer than its environment and will continue upward. Had the air column contained less moisture it would have continued to a higher elevation than 2,000 feet at the adiabatic rate, and cumulonimbus might not have formed. Referring to (B), can you show why?

the problem. Health and economy are adversely affected. Occasionally, lethal smogs have developed when a strong inversion and light winds have persisted for several days. Notable examples occured in Donora, Pennsylvania, in 1948, and in London in 1952. In these cases, a dense fog combined with smoke and other pollutants and became concentrated to the toxic level.

24.7. The Thunderstorm. Thunderstorms are spectacular, violent local storms produced by cumulonimbus cloud and are characterized by squalls, gustiness, turbulence, heavy showers, thunder and lightning, and often hail, which can be as large as four inches in diameter. The strong and gusty surface winds are of serious concern to surface craft and to aircraft on the ground; the strong vertical currents in and below the cumulonimbus cloud

offer danger in flight. Up and down drafts may be so strong as to put dangerous strains and stresses on a plane's structure, or cause loss of control in large aircraft. Visibility is invariably poor in a thunderstorm, ceilings are low, and landings difficult to make. Airplanes may also be seriously damaged by hail; lightning may affect radio antennae, Pitot tubes, and other protruding equipment; icing of the plane's surfaces and fuel system is likely.

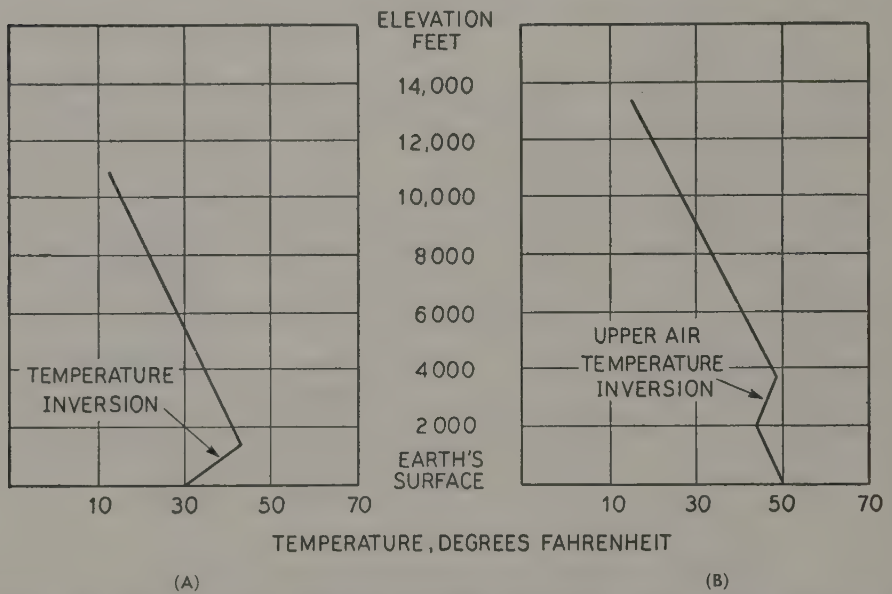


FIG. 24.9 Graph (A) shows a temperature inversion at the earth's surface. Surface inversions are characterized by stability and poor visibility; common at night, they are often associated with ground fog. Graph (B) shows an upper air inversion, the base of which is known as a "Lid." No air from below can penetrate the base of a lid; any smoke, fog, dust or haze present tends to spread out at the base of an upper air inversion.

Thunderstorms form in a number of ways, but all require warm, unstable air of high humidity, and some type of lifting or trigger action. The air parcel must be lifted to a point where it is warmer than the surrounding air, after which it will continue to rise freely until, at some point aloft, the air parcel has cooled to the temperature of the surrounding air. Lifting may occur in several ways, as by heating, mountains, or fronts.

24.8. Life Cycle of the Thunderstorm. The life cycle of the thunderstorm is short, often lasting only from one to two hours, and consists of three stages. In the *cumulus* stage, the cloud is warmer than the outside air, so the cloud air is accelerated upward. There are only updrafts within the cloud at this stage. These updrafts increase with elevation, and the cloud builds rapidly to heights well above the freezing level. During this process, cloud droplets, raindrops, and snowflakes accumulate rapidly in the cloud. When the heavier

elements of this accumulation can no longer be supported by the updrafts, water begins to fall through the cloud. Frictional drag exerted by the water turns the updraft into a downdraft, and heavy rainfall reaches the ground. This is the beginning of the mature stage of the thunderstorm.

In the mature stage, there are updrafts and downdrafts side by side within the cloud. The falling rain and snow, coming from the colder air aloft, cools the downdraft, which spreads out horizontally over the ground as a cool pool of air. Sharp, strong gusts are characteristic of the arrival of the downdraft at the ground; gusts of over 80 knots have been recorded. During the mature stage, the downdrafts gain over the updrafts and the storm reaches the dissipating stage. During this stage, the cloud exhausts its water supply, the rain intensity decreases, and finally the cloud dissolves into irregular lumps or scud at low levels and dense patches and streaks of cirrus at high levels.

The above description applies to a single thundercloud. Generally, there are several of these cells in a cluster, with each cell from 1–6 miles in diameter. The stage of development of these cells will vary from young to old. There is a strong tendency for new cells to form on the forward side of the downdraft of an old cell, so that the life span of a cluster will be much longer than the life of an individual thunderstorm.

24.9. Thunderstorm Patterns. Thunderstorms occur in more or less distinct patterns, which can be grouped into the air mass and frontal varieties.

Air mass thunderstorms from within a uniform mass of air which has the necessary warm, humid and unstable air required for storm development. They occur over land or water almost anywhere in the world, although rarely at high latitudes. Their formation is caused by heating of the air at the surface, so over land they occur most frequently in the afternoon hours, usually on hot, sultry days when winds are light. Strong winds prevent thunderstorm formation by breaking up the vertical currents. Over the oceans, thunderstorms are more frequent at night, because the sea surface temperatures remain almost as warm at night as during the day.

However, temperatures at the upper levels over the ocean drop a considerable amount throughout the night because of radiation. This results in the same type of temperature contrast between the warm surface air and the cooler upper air as is found over the land during summer afternoons. Many persons who have gone to sea may recall clear days and evenings which have been followed by showers before daybreak. While thunderstorms are most common during the warmer seasons over land, they occur at sea with greater frequency during colder months.

Another way in which air mass thunderstorms form is known as *orographic*. Thunderstorms occur quite commonly on the windward slopes of mountains. The upward deflection of the air by the mountains furnishes the trigger action which may result in thunderstorm activity. Even in relatively flat country,

such as the middle western states, thunderstorm activity may break out when air ascends only a few hundred feet in the vicinity of low rolling hills.

Frontal thunderstorms occur along warm and cold fronts and prefrontal squall lines. They occur at any time of day or night. Both warm and cold front thunderstorms result when moist, warm, unstable air is forced to rise over the cold wedges of air lying beneath the frontal surfaces. Line squall thunderstorms form anywhere from 50 to 300 miles ahead of cold fronts under special atmospheric conditions. These thunderstorms are similar to those in a cold front, although tending to be a little more intense and menacing in appearance. Tornadic activity sometimes occurs along with line squalls. Frontal thunderstorms usually form in a line along the leading edge of the front.

24.10. Forecasting and Tracking Thunderstorms. Thunderstorms are forecast by use of data from upper air soundings; the essential problem is that of determining the stability of the air mass (Figure 24.7), and whether or not there will be enough heating or lifting to release the instability. Forecasting thunderstorms is beyond the scope of the layman, although he can often anticipate air mass thunderstorms with accuracy by observing the degree and time of development of cumulus clouds in his vicinity (Section 24.3).

Once formed, thunderstorms are tracked by reports from the network of weather stations, and particularly by radar stations.

24.11. Tornadoes. Although the tornado is the least extensive of all storm types, it is the most violent and sharply defined. Tornadoes may occur in other parts of the world but are most common in the United States, particularly in the plains and southern areas. "Tornado Alley," from Oklahoma north-northeast to Iowa, has more tornadoes than any other area in the world. Tornadoes average only a few hundred yards in diameter and move at 25 to 40 knots along paths which range from a few hundred feet to 300 miles in length and average 25 miles. In the northern hemisphere the wind of the tornado whirls counterclockwise, and it is possible that in many cases velocities approach 400 miles per hour. The tornado may be recognized by its funnel-shaped cloud which builds downward from a cumulonimbus cloud. This funnel may or may not reach the ground and does little damage unless it does touch the ground. The pressure within a tornado is very low, and a building literally explodes when struck, because the normal pressure within a building pushes the walls outward toward the region of the tornado's low pressure. The violent winds then complete the structure's destruction and scatter parts in every direction. The cloud mass is one of condensed vapor, though it also contains much dust and debris picked up along its journey.

Tornadoes are most common in spring and early summer when warm air masses from the Gulf of Mexico encounter cold masses from the northern part of the continent. At that time of year the temperature contrast is greatest

between masses of air of southern and northern origin. Regions along and just ahead of surface cold fronts at that time favor tornado development.

24.12. Waterspouts. Tornadoes at sea are known as waterspouts; they are less violent than those on land. When they touch the sea surface, spray is drawn up into the funnel. They are common off the east coast of North America, in the Gulf of Mexico, and off the coast of Japan and China. The winds in some of the less violent waterspouts rotate clockwise in the northern hemisphere. This type more nearly resembles the common dust whirlwind of land than it does the tornado and is often encountered off the west coasts of Africa, Mexico, and Central America.

24.13. Fog. Fog is a cloud whose base rests on the earth's surface and reduces the visibility to five-eighths of a mile or less. Although the substance of fog is the same as a cloud, the processes of cloud and fog formation are different. Clouds form chiefly because air rises, expands, and cools. Fog results from the cooling of air which remains at the earth's surface. This lowering of air temperature may occur in a number of ways, as described under the following fog types:

Advection Fog. Fog may form, day or night, when warm air sufficiently high in water vapor content flows over cooler land or water surfaces. The cool surface chills the overrunning air, and water vapor of the air tends to condense on particles of dust, smoke, or salt even before the relative humidity reaches 100 percent. The fog may be light, moderate, or dense, depending upon the amount of vapor which condenses. Dense fog is likely if the relative humidity value approaches 100 percent.

The air in which fog forms does not tend to rise because it is being chilled, thus becoming more dense, heavy, and stable. However, if wind speeds are fresh to strong over land surfaces, the air is mixed through a relatively deep layer and individual particles do not remain long enough at the earth's surface to be chilled to or near the dewpoint. Low stratus or stratocumulus clouds form rather than fog. Over the sea, where there is less frictional turbulence than over land, fog may form even when wind speeds are quite strong, and particularly in areas where adjoining warm and cold ocean currents cause wide differences in air and water temperatures. In the famous Grand Bank fogs, it is not uncommon to have persistent 20- to 30-knot winds with thick fog.

Tropical-air Fog is a form of advection fog which does not depend upon air passage over a cold current, but on the gradual cooling of the air as it moves from low to high latitudes. It can occur over both land and water, and is probably the most common type of fog over the open sea. In the United States, it forms some of the most widespread fogs observed anywhere. Tropical-air fog is more common over water than land because of the lesser amount of surface friction. However, the low stratus formed over land because of the friction is about as hazardous to aviation as surface fogs over the oceans.

Radiation Fog. This fog type is a nighttime, over-land phenomenon. During the daytime the earth's surface not only receives heat from the sun but radiates heat as well. At night the incoming heat ceases, but radiation continues, and the earth's surface therefore grows colder throughout the night. The low point is reached just prior to sunrise. Radiation fog does not occur over water surfaces because the heating qualities of water are such as to hold the day-to-night temperature range of water surfaces to 1 degree C or less. Factors which favor the formation of radiation fog are light or gentle winds, sufficiently high humidity, and clear skies. Radiation fog is more commonly known as ground fog. It is a shallow fog through which the sky is usually plainly visible, but it makes airplane landings and take-offs difficult; it obscures landmarks to some extent, thus complicating navigation. Sometimes it forms soon after sunset; at other times it may require a sustained drop in temperature throughout the night before forming.

Radiation fog usually burns off within an hour or so after sunrise. If mixed with smoke, which is particularly common in winter, it forms a greasy "smog" (smoke and fog) which may not be dissipated until later in the morning.

Steam Fog or Arctic Sea Smoke. Steam fog occurs when very cold air passes over much warmer water. The difference in vapor pressure causes rapid evaporation from the water surface into the air, soon filling the air with fog. Steam fog is usually very shallow, and looks like tufts of whirling smoke coming out of the water. If there happens to be an inversion not too far above the water surface, the air between the surface and inversion will fill with steam and become a dense fog. Steam fog is most common in arctic regions, but also occurs frequently over inland bodies of water, lakes and rivers, when cold fall and winter air moves southward.

Frontal Fogs. Fog sometimes forms ahead of warm fronts and behind cold fronts when the rain falls from the warm air above the frontal surfaces into the colder air beneath. Evaporation from the warm raindrops causes the dew-point temperature of the cold air to rise until condensation on existing nuclei takes place. If the winds are strong, or the cold air unstable, stratus or stratocumulus clouds will form instead of fog.

Inversion Fog. This type of fog is typical of the subtropical west coasts, California, for instance. Upwelling of cold water is common along west coasts because of wind action, and the air over this cold water acquires low temperatures and high relative humidity. Above the cool, moist layer lies a temperature inversion which keeps the moist air from rising. Fog forms, as in the advection process, and is very frequent off-shore. At night, as the land cools, the fog works inland.

Ice Fog. Ice fogs occur at temperatures of -30 degrees C or colder, and are found most frequently in inhabited areas. Aircraft running up their engines in temperatures -40 degrees C or lower will quickly cause an airport to be covered with ice fog. Even reindeer, after some exercise, find themselves

surrounded with ice fog caused by evaporation of body liquids which condense and freeze in the bitterly cold air.

24.14. The Forecasting of Radiation Fog. In order to forecast radiation fog over land areas, temperature, sky, and wind conditions must be carefully studied. Also the forecaster must be familiar with local conditions, such as the terrain, proximity of smoke sources, location of nearby water areas, etc. Radiation fog is possible when the sky is expected to be clear or with only high, thin clouds present and the wind not more than force two. The temperature must drop very near to the dewpoint during the night. When the temperature drops to within a degree or two of the dewpoint, radiation fog may be expected soon if it has not already begun to form.

24.15. The Forecasting of Advection and Other Fog Types. The term *advection* is applied to fog formed because of air in horizontal motion. It must be borne in mind that fog may and often does form as a result of many processes operating at the same time. For example, let us consider the case where a warm, moist, easterly wind is blowing over Nebraska. First of all its elevation is increasing because of the gradual rise in the terrain from east to west. This results in expansion and adiabatic cooling of the air, the process mentioned in connection with cloud formation. The air will also undergo cooling if it is passing over colder ground. Then if rain is falling through the air, a third fog formation process is in operation. As in the forecasting of radiation fog, wind direction and velocity, temperature, and humidity conditions must be considered in forecasting advection and other fog types. Unlike radiation fog, the other types may form when skies are cloudy during the day or at night.

24.16. Fog at Sea. Fog is rare at the equator and in the trade-wind belt except along the coasts of California, Chile, and northwest and southwest Africa. On the other hand, it is a common phenomenon of middle and high latitudes, particularly in spring and early summer. The Newfoundland Banks is a region where the Gulf Stream and the Labrador current meet. When warm air from the Gulf Stream overruns the cold water of the Labrador current, dense fog banks result. Likewise, in the northwestern Pacific, fog is common off the coast of Asia where warm air of the Japanese current overruns the cold Kamchatka current. During spring and summer, warm, moist air currents which flow from land to sea produce fog over coastal water areas. A shift in wind direction tends to drift the fog back over adjacent land areas. During fall and early winter, air blowing from sea to land tends to produce fog over coastal sections. Such fog may drift to sea with a reversal of the wind direction.

In the north Pacific Ocean and Bering Sea wide areas of dense fog are common, and at times the fog may extend to elevations of 4000 feet or more. It is caused by air moving northward from high-pressure areas which are centered in the Pacific Ocean at about latitude 35 to 40 degrees north. The air reaches its saturation temperature in passing over the colder waters to the north. Chilling of the air also increases its density so that there is no tendency

of the air to rise and clear. Fog may persist in the Aleutian area when winds are quite strong. When fog-laden wind flows around and over land obstructions, clear spots may be found to leeward; the sun is not effective in burning off this type of fog. During fall and spring months, fog is at a minimum in the Aleutians; in winter, arctic sea smoke is common, and it may at times build up to elevations of several thousand feet above the surface.

24.17. Weather Modification. Of mankind's many dreams for improving his lot upon earth, few have been as widespread and persistent as that of controlling weather. It was not until World War II that it was demonstrated in the laboratory that clouds could be modified and some precipitation produced by scientific means. Since then, greatly increased research activity in the field of weather modification has demonstrated that we still do not have enough knowledge of fundamental atmospheric processes and cloud physics to know how to bring about successful weather modification. The potential benefits to mankind are so great that a vigorous assault on the problem must be made; of primary interest are the ability to increase precipitation, to dissipate low stratus and fog, and to modify severe weather, particularly thunderstorms and tropical cyclones.

We must learn how to reap the benefits of weather modification while, at the same time, avoiding activity which might affect the climatic controls of heat-moisture balances, and general atmospheric and oceanic circulations. Action founded on lack of understanding, which might affect climates, has too many potential hazards—such as flooding of heavily populated coastal plains, turning fertile areas into deserts, and destruction of insect and animal life.

The foundation of weather modification experiments to date involves attempts to alter the life cycle of a cloud or a cloud system by seeding with such substances as water, dry ice, silver iodine, carbon black, and other chemicals. The object is (1) to cause the small cloud droplets to coalesce and reach a size large enough to fall to earth or (2) to seed that part of the cloud composed of supercooled water droplets (droplets still in liquid form but in equilibrium at temperatures below freezing). The seeding agent provides nuclei upon which the supercooled droplets collect and are transformed to ice particles. These ice particles, because of vapor pressure differences between ice and water droplets, collect neighboring water droplets and grow to a size large enough to fall toward or to the ground.

While progress in weather modification has not been rapid, these statements can be made with accuracy:

1. Under specialized conditions, and to a limited degree, rainfall can be increased.

2. Clouds can be modified by artificial means, either increased in size or dissipated. Areas of supercooled clouds 30 by 70 miles in size have been dissipated.

3. Evaporation processes can be altered over water surfaces, and there is evidence that this might be possible over land covered with vegetation.

4. There is evidence that modification of the electrical space charge in the lower atmosphere may affect precipitation from cumulus clouds.

5. We can see and measure the serious results of altering the atmosphere by man-made air pollution.

Various interesting studies are in progress, including a Navy-Weather Bureau effort to modify hurricanes by seeding, triggering release of energy in the high atmosphere by suitable catalysts applied on atomic oxygen and free radicals, and determining the effect of atomic testing upon atmospheric processes. Within the lifetime of the reader, it seems almost certain that man will have a considerable degree of success in his efforts to make the weather do his bidding.

25

Weather Elements, Instruments, and Reports

25.1. Introduction. In order to determine and describe the conditions of the atmosphere or weather at a given time and place, various weather elements must be observed and measured. The reports of the observations are quickly made available for the use of seamen, airmen, forecasters, and others concerned. The values of some elements are estimated or determined visually: others are measured with the aid of instruments, some of which are carried aloft thousands of feet by balloons in order to determine pressure, temperature, moisture, and wind conditions in the vertical.

25.2. Clouds. Cloud observations include notations as to the types which are present, their direction of movement, proportion of the sky that they cover, and height of bases. Twenty-seven variations of the ten basic cloud genera can be recorded. For example, cumulus clouds may be of the relatively flat-topped type of fair, settled weather; or their tops may extend to a considerable height, thereby indicating unstable atmospheric conditions with the possibility of storminess. When cloud types and their variations are observed and reported adequately, many useful inferences may be drawn concerning present weather conditions and imminent changes. This is particularly true at sea, where weather reports are scarce.

25.3. Visibility. By visibility is meant the greatest horizontal distance in a given direction at which it is just possible to see and identify with the unaided eye (a) by day, a prominent dark object at the horizon and (b) at night, a known light source. Each weather station maintains a "visibility weather chart" which shows distance and direction of various permanent landmarks or other reference points used in determining visibility. At major airports, electronic instruments (transmissometers) are used to provide continuous records of runway visual range on specified instrument runways. The runway visual range represents the horizontal distance a pilot will see down the runway from the approach end.

There is a definite relationship between general weather conditions and the visibility. When the air is warmer than the underlying surface, it tends to be stable, and poor surface visibility due to fog, haze, smoke, drizzle, or dust may prevail. Poor visibility is often associated with clouds of the stratus

type. If the surface is warmer than the overlying air, horizontal visibility at the surface tends to be good. This is beacuse particles that restrict visibility are carried upward by the surface air which expands and rises when heated by the warm surface. Any clouds present would be the cumulus type. Fog and falling snow are two of the most serious restrictions to visibility, because the visibility can deteriorate so rapidly with the occurrence of either. Fog may be anticipated when the temperature and dewpoint values are approaching each other. This is especially true when the air has considerable foreign matter present, such as dust, smoke, and haze. Visibility is of prime importance in navigation at sea and to landing aircraft.

25.4. State of the Weather. A weather report always includes a reference to the state of the weather. This, in general, refers to the existence, imminence, or absence of precipitation, but obstructions to vision are also included in this part of the code. It is possible to record and report 100 different states of the weather, ranging from cloudless skies to heavy thunderstorms with hail. Other conditions which can be reported with existing weather codes include low fog, haze, distant lightning, smoke, and various degrees of fog, rain, snow, showers, drizzle, squalls, etc. Definitions of some of the more frequently reported state of weather elements follow.

Dust. This consists of minute earth particles which are picked up and carried along by the wind. Distant objects have a more or less grayish or tan appearance, depending on the amount of dust present. Although there is always some dust in the air, appreciable amounts are usually of local origin. Blowing dust is reported when sheets or clouds of it are carried along in a strong wind.

Haze. Haze is composed of very finely divided particles of matter from land areas or of salt particles from the sea. They are much smaller than dust particles. Haze gives distant objects a pale blue or sometimes yellow appearance. At a distance the details of objects disappear, and the objects stand out in silhouette fashion.

Smoke. Particles resulting from combustion are know as smoke. Except for its odor it might be confused with fog, dust, or haze, especially in light amounts. It is common in the vicinity of cities, especially to leeward of industrial areas. It gives a reddish tinge to the sun's disk at sunrise and sunset.

Hydrometeors are defined as water in solid or liquid form falling through the air. The following types are noteworthy in meteorology:

Drizzle. Drizzle is composed of minute liquid droplets so numerous they seem to fill the air. This form of precipitation originates in stratus clouds or fog. Drizzle particles seem to float in the air and appear to follow even slight motion of the air. Drizzle is characteriscally associated with poor visibility. When the droplets instantly freeze to objects which they strike, they are known as freezing drizzle.

Rain. Rain is drops of water larger than drizzle falling from clouds. The drops are usually sparser than those of drizzle. When they freeze to objects, the condition is known as freezing rain.

Sleet. In the United States sleet is defined as frozen raindrops. In England and in the International Weather Code, as well as in popular press vernacular, a mixture of rain and snow is known as sleet.

Hail. Hail is almost exclusively a phenomenon of violent or prolonged thunderstorms. Hail consists of ice balls or stones with diameters ranging from $\frac{1}{5}$ inch to 4 inches or more, which fall either detached or fused in irregular lumps. They may be transparent or composed of alternate clear and opaque, snowlike layers.

Snow. This form of precipitation from clouds consists of white or translucent ice crystals mainly in branched hexagonal shapes often mixed with simple ice crystals.

Showers. This form of precipitation is associated with cumuliform clouds and is characterized by beginning and ending suddenly. Showers, usually of short duration, often occur in a series with periods of fair conditions between individual shower periods. Unstable atmospheric conditions are indicated by showers, and the form of precipitation may be either snow or rain. Snow showers are sometimes known as *snow flurries.*

25.5. Atmospheric, or Barometric, Pressure. The value of the atmospheric pressure is one of the most important elements in reporting and forecasting the weather. It is particularly significant when considered in connection with the direction and speed of the wind and cloud types and sequences. Average pressure values reveal much regarding the prevailing or climatic characteristics of a region. Pressure variations are not for the most part perceptible to human senses. It is the one element that cannot be estimated; its value must be determined instrumentally. Pressure-measuring instruments in common use are the mercurial barometer, aneroid barometer, and the barograph.

The *mercurial barometer* is standard at land stations, but most ships now carry only the *aneroid* type. Mercurial barometers are direct reading, but corrections are applied for temperature, gravity, elevation above sea level, also each instument has an individual correction which must always be applied. The mercurial barometer is essentially a glass tube with one end closed. It is filled with mercury and inverted so that the open end projects into a well or cistern. The top of the mercury in the tube will then lower until the column just balances a column of the atmosphere of the same cross section as that of the mercury. The height of the mercury column as measured from the top of the liquid in the cistern is an expression of the atmospheric pressure. When the atmospheric pressure increases, the mercury rises; a decrease in atmospheric pressure causes the column to decrease in height. In nautical terminology, the mercurial barometer was commonly called "the glass," a contraction of "weather glass." High pressure was known as a "high glass," low as a "low glass." A high glass was associated in general with fair weather conditions, whereas a low glass often meant cloudiness, rain, increased windiness, and stormy conditions in general.

The scale on European mercurial barometers is usually in terms of millimeters; in the United States, inches are used. Readings may be made to thousandths of an inch by means of a vernier scale. The value in inches is converted to units of millibars. This unit has been adopted in scientific meteorological work because it represents a force, whereas mercury in inches is a unit of length. Isobars on weather maps are drawn in terms of millibars rather than inches. A millibar is equivalent to 1000 dynes per square centimeter; 1000 millibars are equivalent to 29.53 inches of mercury. The standard pressure of 29.92 inches equals 1013.2 millibars (see Fig. 25.1).

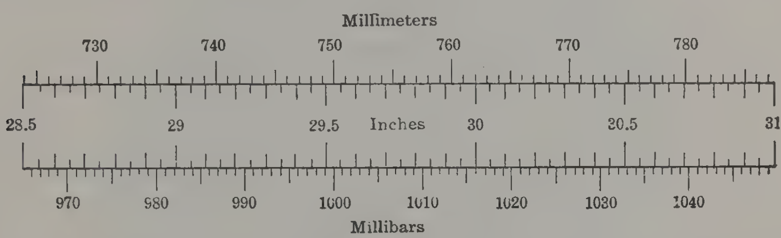


FIG. 25.1 THE RELATIONSHIP BETWEEN THE MILLIMETER, INCH, AND MILLIBAR SCALES. European barometers are commonly fitted with millimeter scales, while instruments in the United States and England are read in inches. The millibar unit is used on weather maps.

The aneroid barometer (Fig. 25.2) is a small, convenient instrument operating on a principle different from that of the mercurial type. It consists essentially of a corrugated metallic chamber or cell exhausted of air. The cell is prevented from collapsing by means of a strong steel spring. One side of the cell is arranged so that it responds to variations in atmospheric pressure by expanding and contracting. This motion is magnified by a system of levers and chains and transmitted to a hand on the dial of the instrument. Temperature differences are compensated for by means of a bimetallic link of brass and steel. It is necessary occasionally to test and compare aneroid barometers with standard mercurial instruments.

Barographs (Fig. 25.3) are instruments which afford a continuous record of atmospheric pressure and consist of two units. First, the motion of a series of small aneroid cells is magnified and transmitted to a pen by means of a system of levers and chains. Second, a card mounted on a drum is rotated slowly on a vertical axis by means of a clock mechanism. The pen traces a continuous record of the barometric pressure on the card. The barograph is a most useful instrument because it not only shows the present reading but, even more important, whether or not pressure values are rising or falling and the rate of changes. One of the most significant elements of a weather report is the *pressure tendency* during the three-hour period prior to the report. The tendency includes both the character of pressure change, i.e., whether the pressure is rising or falling, etc., and the net amount in tenths of millibars of such change. The barograph trace shows the pressure tendency at a glance. The

barograph, like all aneroid barometers, must be compared frequently with standard mercurial instruments. The card on the drum may record the pressure for four or seven days, depending on the type of barograph in use. Figure 25.4

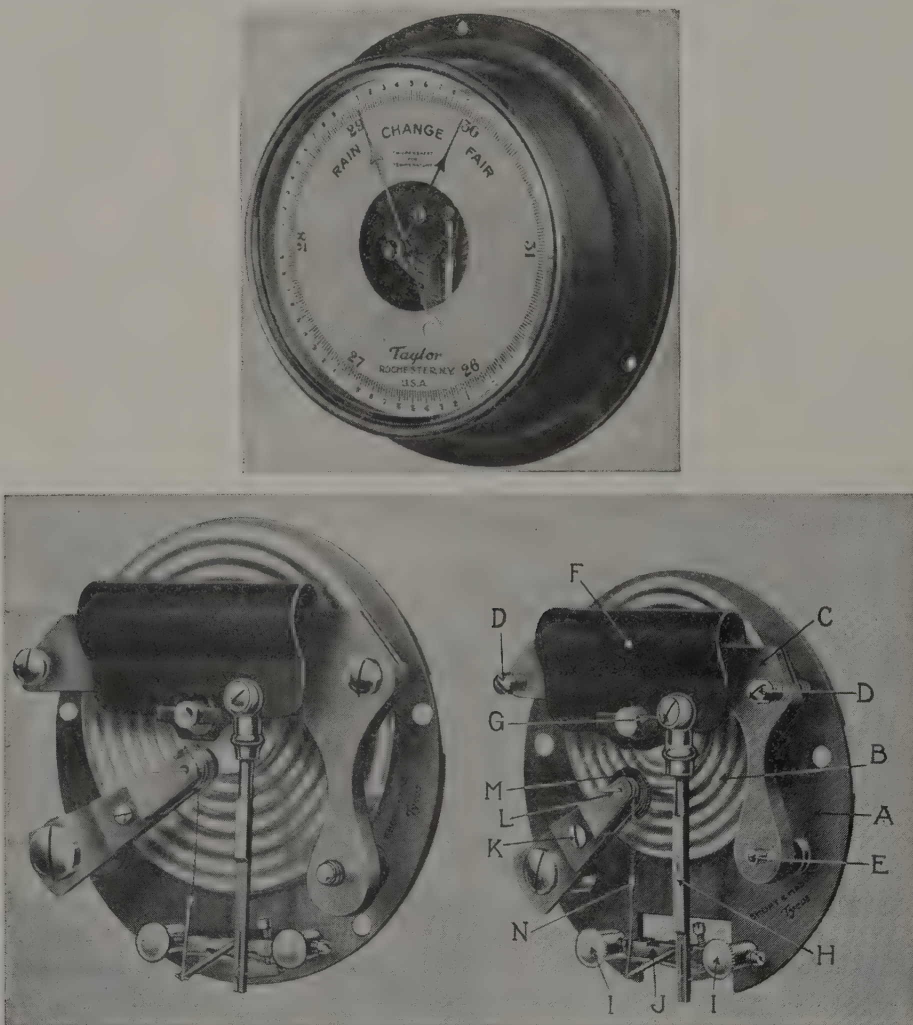


FIG. 25.2 ANEROID BAROMETER. *Courtesy Taylor Instrument Companies*

shows a typical barograph trace. It will be noted that pressure values are indicated along the vertical scale, whereas time units are marked off on the horizontal scale. The time lines are curved because the pen that records pressure values is pivoted at the aneroid unit.

25.6. Temperature. Air temperature is measured by thermometers or other devices, graduated in degrees Fahrenheit (freezing 32 degrees, boiling 212 de-

grees) or, by many nations, in degrees Centigrade, or Celsius (freezing 0 degree, boiling 100 degrees). To be representative, air temperatures near the surface must be measured under conditions where there are no influences on the thermometer except the free air. Hence, thermometers at land stations are exposed in white shelters which have insulated roofs and louvered sides and are raised five to six feet off the ground. At sea, temperature measurement in a shelter is not satisfactory because at any one location in the ship, conditions are not always the same. For example, at one time heat may issue up from below

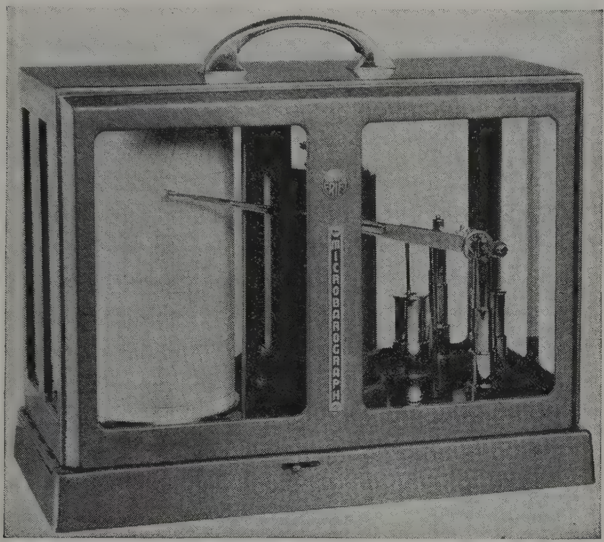


FIG. 25.3 MICROBAROGRAPH. *Courtesy Friez Instrument Div., Bendix Aviation Corp.*

decks to affect the thermometer; at other times the prevailing wind may carry the heat in the other direction. There is also the problem of temperature differences on leeward and weather sides. Temperature and humidity measurements are made aboard ship with the sling psychrometer (Section 25.7) or the portable aspiration thermometer. The latter consists of a tubular shield, artificially ventilated by means of a mechanically driven fan attached to the top of the instrument. The *aspiration* thermometer may be taken to any part of the ship for readings, and it is not affected by the direct rays of the sun.

The *thermograph* is an instrument which affords a continuous record of the air temperature. A commonly used thermograph is one which uses a bimetallic strip as the reactor. Two thin, curved sheets of metal of widely different thermal expansion are welded together. When the temperature changes, the two metals expand unequally, and the curvature of the strip changes. This change is transferred through levers to a pen which moves up and down on a card which is wrapped around a drum. The drum is driven slowly around a vertical axis by a clock mechanism. The values shown by such an instrument

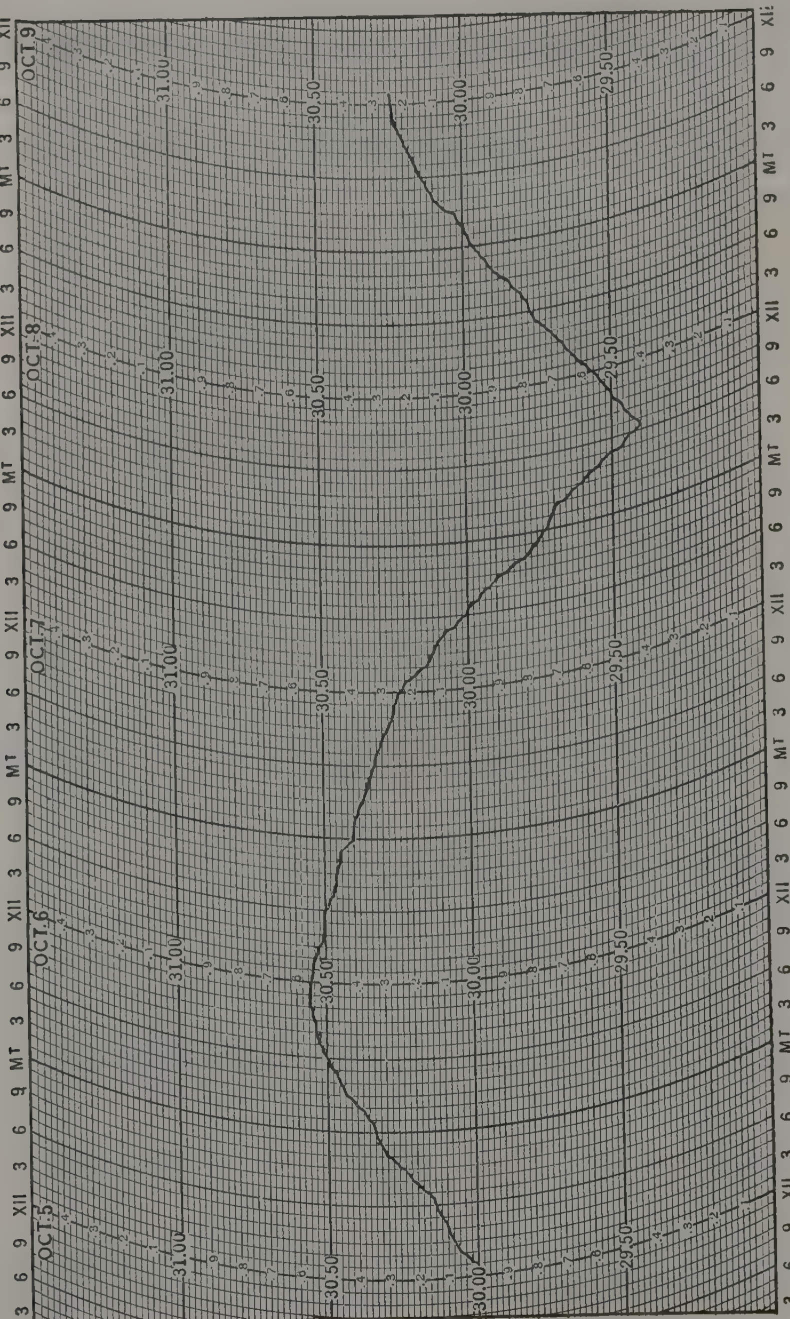


FIG. 25.4 TYPICAL BAROGRAPH TRACE

are subject to error, but if the thermograph is compared frequently with a good mercurial thermometer, the errors may be determined and corrected.

A *maximum* thermometer shows the highest temperature which occurred since the instrument was last read and set. It is similar to an ordinary thermometer except that the bore has a constriction in it just above the bulb, like the clinical or fever thermometers used by doctors. When the mercury in the bulb warms and expands, mercury will flow past the constriction and rise in the bore, but mercury will not flow back into the bulb when the temperature decreases. To force the mercury back into the bulb it is necessary to whirl or shake the thermometer.

A *minimum* thermometer shows the lowest temperature which occurred since it was last read and set. This is an alcohol thermometer with a small glass index which looks like a two-headed pin in the alcohol column. The top of the alcohol, the meniscus, holds the pin at the top by surface tension. As the alcohol retreats with lower temperature, the index is dragged down. Then, as the temperature rises, the liquid leaves the index, which remains with its outer end still showing the lowest temperature reached.

25.7. Dewpoint and Relative Humidity. The water vapor content of the air may be obtained by means of *psychrometer* readings. The psychrometer consists of two thermometers, one of which is called the *dry-bulb,* the other, the *wet-bulb.* There is no difference in the two thermometers, but the bulb of one is fitted with a piece of cloth. This instrument may be carried to any part of the ship to obtain suitable exposure. When a reading is desired, the cloth on the wet-bulb thermometer is moistened. The psychrometer is then whirled. If the air is saturated with water vapor, as during a dense fog, there will be no evaporation from the wet-bulb, and the two thermometers will read the same. When the air is not saturated, evaporation will take place from the wet-bulb. The evaporation is associated with cooling, and the reading of the wet-bulb will be lower than the reading of the dry-bulb thermometer. For any given air temperature, the greater the difference in the dry- and wet-bulb readings, the lower will be the dewpoint and relative humidity. In order to get the dewpoint and relative humidity values it is necessary to look up their values in tables of dewpoint and humidity. The dry-bulb temperature and the difference between the dry- -and wetbulb readings are the two arguments which are used in entering the tables. The aspiration psychrometer, described in Section 25.6, is gradually replacing the sling psychrometer, described above, for humidity measurements.

A continuous record of relative humidity is made by means of a *hygrograph.* The recording pen is actuated by a unit of human hairs which expand and contract with changing humidity conditions. Values are recorded by the pen on a card which is mounted on a revolving drum driven by a clock mechanism. The idea of using human hair as a humidity indicator is not new. An old American Indian saying was, "When the locks of the Navajoes turn damp

in the scalp house, surely it will rain," which fits in with the increased humidity usually found as a low pressure center approaches.

25.8. Wind Direction. The wind direction is the direction *from* which the wind blows. For example, a wind blowing from the northwest toward the southeast is known as a northwest wind. The direction may be estimated or it may be determined by means of a wind vane. *Wind vanes* point toward the direction from which the wind is blowing. Vanes may be wired to an indicator in the weather office or some other location so that the wind direction may be known at a glance. In most weather offices, a permanent record is made of the readings.

In order to estimate the wind direction by the appearance of the sea, the crests of the small ripples are considered to be perpendicular to the wind direction. In strong winds the foam streaks show the wind direction reliably. At night and during heavy rains when the ripples cannot be seen, it may be necessary to note the apparent direction of the wind. This is the direction from which the wind seems to blow; it is the resultant of the true wind and the ship's movement. Wind vanes on board ship also register the apparent wind. To determine the true wind direction and velocity from the values of the apparent wind direction and force and the true course and speed of the vessel, one of several methods may be used—the plotting or maneuvering board, the true wind computer, tables, or direct-reading instruments.

25.9. Wind Velocity. Wind speed may be estimated or it may be measured by means of an *anemometer*. It is expressed in knots, miles per hour, meters per second, or in Beaufort force numbers. The Beaufort scale of wind force, shown on pages 522–523, is useful in estimating wind forces. Experienced seamen become expert at estimating wind speed and direction by observing waves, funnel smoke, flags, and even sounds. This is fortunate, since 90 percent of the wind information from ocean areas comes from merchant ships with no wind observation equipment.

25.10. Upper Air Winds. Some shore and ship meteorological stations are equipped to determine the direction and force of the wind at various heights above the earth's surface. This information is important to airmen for navigation and fuel consumption planning. Forecasters are also interested in upper air wind data because it indicates sources of air masses and other processes that determine cloudiness, precipitation, and other weather conditions.

Pilot balloon (*PIBAL*) observations are widely used to get upper air wind data. Small rubber balloons are inflated with hydrogen or helium so that they have a definite rate of ascension. After a balloon is released, it is watched through the telescope of a theodolite, an instrument that resembles a surveyor's transit. By means of scales on the theodolite, the azimuth and the vertical angle of the balloon are determined at one-minute intervals. Since the balloon has a predetermined rate of ascension, its height is known at all times; therefore by means of trigonometry, the height, together with the azimuth and vertical angle readings, is used to compute the wind force and

direction through each successive layer. Radiosonde balloons (Section 25.14) are tracked by the same method to provide measurement of winds aloft.

For example, let us suppose that a 30-inch balloon is inflated so that it has an ascension rate of 600 feet per minute. If the balloon goes straight up after release, it is obvious that calm conditions prevail at the elevations corresponding to that portion of the balloon's journey. If after 2 minutes the balloon is located south of the 600-foot observation we know that a north wind is blowing between 600 and 1200 feet.

A pilot balloon observation terminates once the balloon gets out of sight because of clouds or distance. During World War II, when wind information at high levels and above cloud layers became of critical importance, balloons were equipped with radar targets (reflectors), and tracking was done by radar. This method of obtaining accurate upper air winds has been generally replaced by tracking the signal from a radiosonde transmitter with radio direction-finding equipment. Winds measurements obtained by these two methods are called RAWINS.

25.11. Ceiling. The ceiling is the vertical distance between the earth's surface and the lowest layer of obscuring phenomena, such as clouds, that covers more than one half of the sky. The ceiling value is important in aviation.

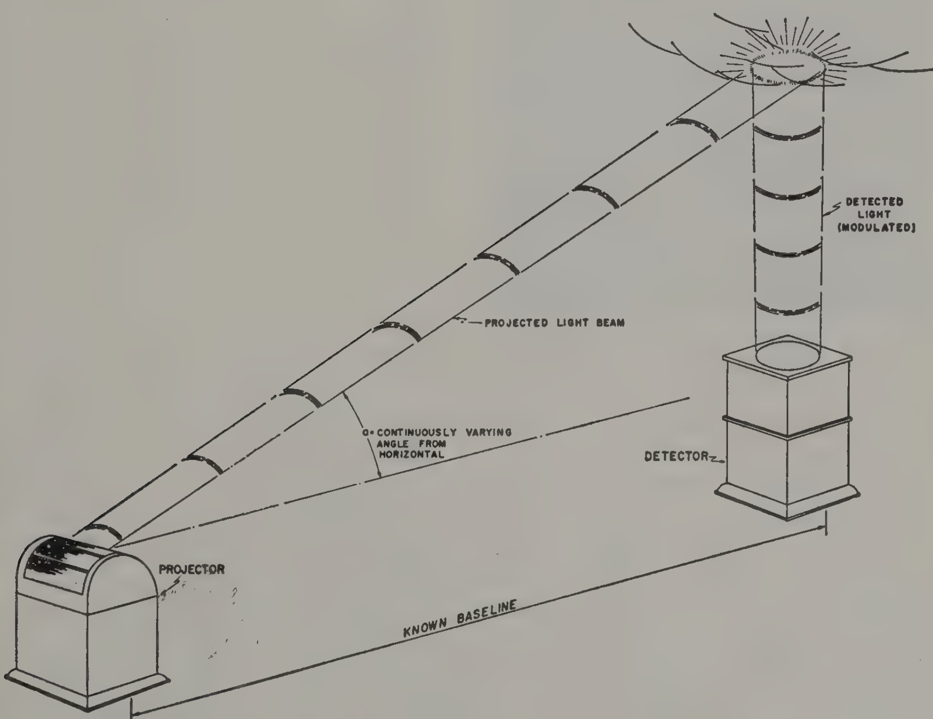


FIG. 25.5 TYPICAL INSTALLATION OF ROTATING BEAM CEILOMETER

Ceiling values may be estimated or they may be measured. Previous ceiling values, weather trends, and conditions reported from surrounding areas, must be considered in estimating ceilings. Aircraft reports are an important source of ceiling information; these are obtained in "let downs" or in level flight at the base of cloud decks.

Many shore stations are equipped with ceilometers, which are instruments used to determine ceiling conditions both at night and during daylight hours (see Fig. 25.5).

25.12. Ocean Surface Temperature. Observations from ships at sea include the temperature of the water at the surface. This may be obtained by a carefully installed thermometer in the condenser intake. Water temperature is important in the forecasting of fog, clouds, mixed layer depth, and other phenomena.

25.13. Marine Automatic Weather Stations. To fill the gaps in key ocean areas, sea-going automatic weather stations are being developed, and will soon become operational. The U.S. Navy has developed one version called the NOMAD (Figure 25.6) which has been tested in the Gulf of Mexico and off the Virginia Capes.

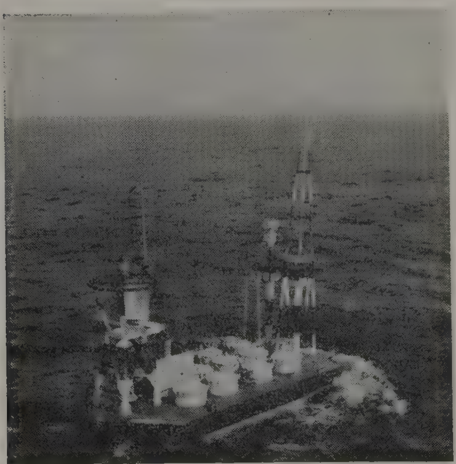


FIG. 25.6 NAVAL OCEANOGRAPHIC METEOROLOGICAL AUTOMATIC DEVICE (NOMAD)

These automatic stations relay weather observations every six hours, and every hour if the winds are over 21 knots. Winds, temperature, and pressure are now included in the reports, with humidity to be added later.

In 1964, the Gulf of Mexico NOMAD successfully tested a nuclear device to provide power for radio transmissions and instrument operation.

Later models of the Nomad and other buoys will provide oceanographic as well as meteorological information, water temperatures from 24 selected levels between the water surface and a depth of 1000 feet. Also, an inertial device is being developed to provide information on wave and swell height.

25.14. Temperature, Humidity, and Pressure at High Levels. The *radiosonde* is an instrument which is used to obtain the pressure, temperature, and humidity at various levels above the earth's surface. Only a limited number of land stations and ships are equipped to make this type of weather observation known as a RAOB. The instrument consists of a container with elements for determining the pressure, temperature, and humidity of the upper air and with a battery-operated radio transmitter by means of which the measurements are transmitted to a receiver located at the meteorological sta-

tion. The instrument is carried aloft by a free balloon to heights consistently, near 100,000 feet and many times between 100,000 and 150,000 feet. When the balloon bursts, the radiosonde descends by means of a parachute.

Information obtained by means of RAOBS is made use of immediately in the preparation of weather maps and charts.

Weather reconnaissance flights often use a *dropsonde* to obtain upper air data. This instrument is similar to the radiosonde and is parachuted to the earth from the aircraft. The aircraft orbits within signal reading distance of the dropsonde and collects the data transmitted in a manner similar to that of the radiosonde receiver.

25.15. Rocketsondes. As the space age emerges, the requirements for high-level atmospheric information increase rapidly. Environmental factors are of importance in the design, launching, and re-entry of missiles and space systems. For design of missiles and space systems, information is needed as to the mean conditions of density, temperature, and wind in the 100,000–350,000 foot layer. (Radiosondes and Rawins give the information from surface to 100,000 feet.) Research for systems of the future require that the level be raised to 600,000 feet.

Meteorological and geophysical satellites provide atmospheric information in the horizontal at flight level. Rockets provide density, wind, and temperature information in the vertical—reliably to 200,000 feet, less reliably above this. Temperature and density to 100,000 feet are obtained from bead thermistors. Between 100,000 and 200,000 feet two methods are employed. In one, a sphere of known displacement is inflated at about 250,000 feet. It reaches terminal velocity after falling to 200,000 feet, and is tracked by precision radar to collapse-point near 100,000 feet. Density is calculated from the rate of descent, temperature from the density, and winds are read directly. Another method uses a parachute, ejected at high levels and carrying bead thermistors. Here, the temperature is a direct input, density is computed from temperature and, again, winds are determined directly from the radar track.

Above 200,000 feet, the measurement problem increases in difficulty. Methods under development include (1) measurements by a ram air gauge, (2) release of small grenades at 2 mi. intervals, which make it possible to determine time of travel and direction of sound waves and (3) falling spheres (as already described).

25.16. Weather Satellites. The newest means of obtaining information about the state of the atmosphere is from weather satellites, which circle the earth at altitudes over 400 miles and transmit pictures of the earth and its cloud cover along a path 750 to 1000 miles wide. For the first time, it is possible to see the cloud pattern of a whole storm, such as that of a hurricane, Figure 25.7. In addition to daylight pictures, weather satellites are equipped with infrared radiometers which, by sensing the differences in heat radiation from the earth and the clouds, make it possible to determine cloud patterns at night.

Research on how to obtain maximum use of satellite data is progressing well. Previously, the meteorologist's methods were based upon looking upward at cloud systems from scattered observation points; now, he must learn to use continuous data with a view from the top. Already, operational use can be made of the pictures which show configuration and location of extra-tropical and tropical cyclones, presence or absence of clouds, and location of jet streams. Hurricanes and typhoons have been discovered by satellites. Hurricane Carla, in 1961, was discovered by TIROS III in time to make possible the largest mass evacuation ever to take place in the United States—more than 350,000 people fled from the path of this severe hurricane. Research is now underway, the results of which may make it possible to use satellite observations to determine with accuracy the intensity of storms, cloud thickness, state of the sea, surface winds, and to be able to monitor movement and changing configuration of ice packs. A further use of weather satellites will be as collectors and transmitters of data from outlying manned or automatic weather stations, weather and oceanographic buoys, and from instrumented balloons floating freely at known atmospheric levels.

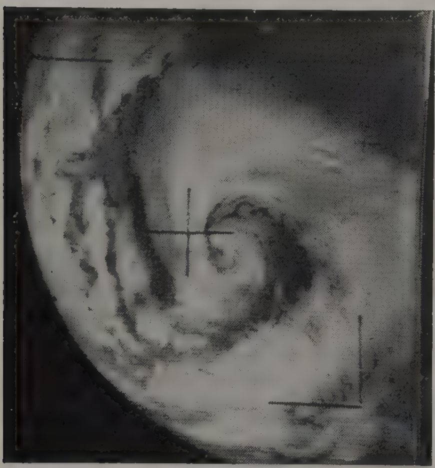


FIG. 25.7 *TIROS* IN ORBIT 154/153 4 FEBRUARY 1965 SHOWING NORTHERN HEMISPHERE CYCLONE

25.17. Transmission of Weather Observations. By international agreement, the ships of all maritime nations use the same code for the transmission of weather reports by radio. A coded ship weather message consists of a series of four, six, or more five-digit numbers, the number of groups depending upon whether a short, an abbreviated, or a full message is sent. Coded reports from ships differ slightly from land station messages because ships must report their position by latitude and longitude. Ship reports usually consist of the first six groups of a full weather message. This is known as an abbreviated message, and the symbols of these groups are as follows:

$YQL_aL_aL_a$	$L_oL_oL_oGG$	$Nddff$	$VVwwW$	$PPPTT$	$N_hC_LhC_MC_H$
20384	58718	61820	94100	11558	44620

The top line shows the symbols that stand for the data which is to be coded and transmitted by radio. The second line is the coded message ready to be transmitted as six numbers of five digits each, preceded by the word *ship*. The meaning of the symbols and the digits shown in the sample report above is as follows:

Y	The day of the week; 2 is the figure which codes Monday. Seven digits represent the seven days of the week.
Q	The octant of the earth; 0 represents the octant in the northern hemisphere between 0 and 90 degrees west longitude. The digits 0–3 stand for the four octants in the northern hemisphere, while 5–8 are used for the octants of the southern hemisphere. It is always necessary to specify the octant in a report, because latitude is not indicated in reports as north or south; longitude is not designated east or west.
$L_aL_aL_a$	The latitude of the ship when the observation was made; 384 stands for 38.4 degrees.
$L_oL_oL_o$	The longitude; 587 is the code for 58.7 degrees.
GG	The Greenwich civil time to the nearest hour, on the 24-hour scale; 18 is the code for 18^h G.C.T.
N	Total amount of cloud; 6 means that six-eighths of the sky is covered by clouds.
dd	The true direction, in 10's of degrees, from which the wind is blowing; 18 means that the wind is blowing from 180 degrees.
ff	The wind speed in knots; the number 20 in the code stands for the wind speed in knots.
VV	The visibility or horizontal distance at which objects can be seen in daylight or at which lights can be seen at night; 94 stands for ½ nautical mile (1000 meters).
ww	The present weather at the time of observation; the figure 10 stands for light fog, visibility 1000 meters (1100 yards) or more.
W	Past weather; the digit 0 means that the weather within the six-hour period immediately preceding the observation was clear, or only a few clouds were present.
PPP	The barometric pressure, in millibars and tenths (initial 9 or 10 omitted). The values refer to sea level and include all corrections for index errors, temperature and gravity; 115 stands for 1011.5 millibars.
TT	The air temperature, in whole degrees Centigrade (celsius).
N_h	Fraction of celestial dome covered by low clouds. If there are no low clouds, report that fraction covered by middle clouds.
C_L	Clouds of types stratocumulus, stratus, cumulus, and cumulonimbus; 4 refers to stratocumulus formed by the spreading out of cumulus; cumulus also often present.
h	The height of base of low cloud above the sea (or ground); 6 means 3500 to 5000 feet.
C_M	Clouds of types altocumulus, altostratus, and nimbostratus; 2 stands for thick altostratus or nimbostratus.
C_H	Clouds of types cirrus, cirrostratus, and cirrocumulus; 0 means that there are no high clouds present.

25.18. The Use of Weather Reports. Ship and land stations, regardless of location, observe and record weather conditions simultaneously every six hours, starting at midnight Greenwich time. The reports are transmitted by landline or radio to collection and control centers, and there further relayed so as to reach all users in the shortest possible time. These reports are used for the preparation of weather charts, from which forecasts are made. The forecasts are transmitted on assigned frequencies and at specified times to any party that can receive the broadcast. In addition to forecasts, a general description of the weather map is also broadcast, along with selected surface reports from which a ship may prepare its own weather map if it so desires. Advancements in radio facsimile have made it possible to broadcast facsimiles of the current weather maps in picture form. Many merchant ships and a great number of military ships are equipped to copy this form of transmission.

Complete weather broadcast schedules for various parts of the world are contained in the following publications: H.O. 118 and H.O. 119, *Radio Weather Aids,* issued by the Hydrographic Office of the Navy Department; *Weather Service for Merchant Shipping and Coastal Warning and Facilities Charts,* published by the U.S. Weather Bureau; *Information for Shipping,* Publication No. 9. TP 4 (Volume D) published by the World Meteorological Organization.

25.19. Plotting Reports on the Weather Map. Persons who regularly receive and decode reports soon learn to do so with very little reference to code tables. An element—for example, wind force—always occupies the same position in the same code group. If a weather element is missing for any reason, the observer who makes up the report at the point of origin always fills in with x's the space which the element would ordinarily occupy in the message.

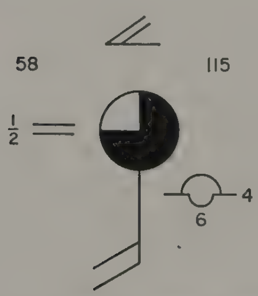


FIG. 25.8 ABBREVIATED WEATHER MESSAGE AS IT WOULD BE ENTERED ON A WEATHER MAP. The message described on page 518 would look like this when entered on a map.

Figure 25.8 shows the scheme used for plotting on a weather map the data of the ship's report appearing on page 518. First, the position of the ship is located on the chart, and a small circle is drawn there. The various weather elements of the report are then arranged at definite positions with reference to the circle. By using the same position for the same element each time there is then no question as to what element a figure represents. The circle is usually filled in first to represent the amount of the sky that is covered by clouds. Next, the arrow shaft is drawn to represent the wind direction. The shaft is always extended toward the direction from which the wind blows. The wind force is represented by feathers or barbs at the end of the shaft. One half of a barb stands for 5 knots, and one long barb stands for 10 knots. In Fig. 25.8 the wind force is 20 knots. Once the arrow shaft is drawn,

the other elements may be recorded. If the arrow were to be drawn in last, it might extend through some of the other data with the danger of obliterating part of them.

Symbols are used to depict the wind direction and force, cloud forms, the present and past state of the weather, and the amount of clouds covering the sky. Coded figures represent the amount of sky covered by low clouds. The elements represented directly by figures are the temperature, visibility and the pressure (tens and units of millibars).

25.20. Criteria for Wind Warnings. *Wind Warning Terminology in Common Usage by the U.S. Weather Bureau and the U.S. Navy.* Warnings of winds associated with closed cyclonic circulations of tropical origin are expressed in the following terms:

Type of Warning	*Corresponding Wind Speed*
Tropical depression	Winds up to 33 knots
Tropical storm	Winds between 34 and 63 knots
Hurricane/typhoon	Winds of 64 knots or greater

Warnings of winds associated with weather systems located in latitudes outside tropical regions, or by systems of tropical origin other than closed cyclonic circulations, will be expressed in the following terms:

Type of Warning	*Corresponding Wind Speed*
Small craft warning	Winds up to 33 knots (use in coastal and inland waters only)
Gale warning	Winds between 34 and 47 knots
Storm warning	Winds of 48 knots or greater

Wind Warning Terminology Used by the U.S. Weather Bureau for Coastal Warning Displays. Warnings of winds for coastal display purposes are issued by the U.S. Weather Bureau in accordance with the following criteria:

Type of Warning	*Corresponding Wind Speed*
Small craft warning	Winds up to 33 knots
Gale warning	Winds between 34 and 47 knots
Whole gale warning	Winds between 48 and 63 knots
Hurricane warning	Winds of 64 knots or greater

TABLE 25.1. BEAUFORT

Beaufort No.	Knots (Mph)	Description	Effect at Sea	Effect Ashore
0	Less than 1	Calm	Sea like a mirror.	Smoke rises vertically.
1	1–3 (1–3)	Light air	Ripples with the appearance of a scale are formed but without foam crests.	Does not move wind vanes, but wind direction shown by smoke drift.
2	4–6 (4–7)	Light breeze	Small wavelets, still short but more pronounced; crests have a glassy appearance and do not break.	Wind felt on face; leaves rustle; ordinary vane moved by wind.
3	7–10 (8–12)	Gentle breeze	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses.	Leaves and small twigs in constant motion; wind extends light flag.
4	11–16 (13–18)	Moderate breeze	Small waves, becoming longer; fairly frequent white horses.	Raises dust and loose paper; small branches are moved.
5	17–21 (18–24)	Fresh breeze	Moderate waves, taking a more pronounced long form; many white horses are formed. (Chance of some spray.)	Small trees in leaf begin to sway; crested wavelets form on inland waters.
6	22–27 (25–31)	Strong breeze	Large waves begin to form; the white foam crests are more extensive everywhere. (Probably some spray.)	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
7	28–33 (32–38)	Moderate gale (high wind)	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind. Spindrift begins.	Whole trees in motion; inconvenience felt in walking against wind.
8	34–40 (39–46)	Fresh gale	Moderately high waves of greater length; edges of crests break into spindrift. The foam is blown in well-marked streaks along the direction of the wind.	Breaks twigs off trees; generally impedes progress.
9	41–47 (47–54)	Strong gale	High waves. Dense streaks of foam along the direction of the wind. Sea begins to roll. Spray may affect visibility.	Slight structural damage occurs (chimney pots and slate removed).
10	48–55 (55–63)	Storm	Very high waves with long overhanging crests. The resulting foam in great patches is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea takes a white appearance. The rolling of the sea becomes heavy and shocklike. Visibility is affected.	Seldom experienced inland; trees uprooted; considerable structural damage occurs.
11	56–63 (64–73)	Violent storm	Exceptionally high waves. (Small and medium-sized ships might for a long time be lost to view behind the waves.) The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected.	Very rarely experienced; accompanied by widespread damage.
12	Above 63 (73)	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.	

* To attain a fully arisen sea for a certain wind speed, the wind must blow at that speed over a minimum distance (fetch) for a minimum time (duration). When winds are 50 knots or more, the required fetch and duration for a fully arisen sea rarely occur. The wave heights shown in the last column, "Average Wave Height" represent what will be found on the average at given wind speeds.

Wave heights refer only to wind waves, and swells from distant or old storms are nearly always superimposed on the wind-wave pattern.

Practical Methods of Observing and Forecasting Ocean Waves, Pierson, Neuman, James, H.O. Pub. 603, 1955.

† H.O. 118A.

CALE OF WIND FORCE

Wind and Sea Scale for Fully Arisen Sea *								
	Wave Height-Feet							
Wind Speed (Knots)	Average	Significant Average ⅓ Highest	Average 1/10 Highest	Average Period	Average Wave Length	Minimum Fetch (Nautical Miles)	Minimum Duration (Hours)	Average Wave Height † (Maximum)
0	0	0	0	—	—	—	—	—
2	0.05	0.08	0.10	0.5	10″	5	18 min	
5	0.18	0.29	0.37	1.4	6.7 ft	8	39 min	
8.5	0.6	1.0	1.2	2.4	20	9.8	1.7 hrs	
10	0.88	1.4	1.8	2.9	27	10	2.4	2(3)
13.5	1.8	2.9	3.7	3.9	52	24	4.8	3½(5)
16	2.9	4.6	5.8	4.6	71	40	6.6	
18	3.8	6.1	7.8	5.1	90	55	8.3	
19	4.3	6.9	8.7	5.4	99	65	9.2	6(8½)
20	5.0	8.0	10	5.7	111	75	10	
22	6.4	10	13	6.3	134	100	12	
24.5	8.2	13	17	7.0	164	140	15	9½(13)
26	9.6	15	20	7.4	188	180	17	
28	11	18	23	7.9	212	230	20	
30.5	14	23	29	8.7	258	290	24	13½(19)
32	16	26	33	9.1	285	340	27	
34	19	30	38	9.7	322	420	30	
37	23	37	46.7	10.5	376	530	37	18(25)
40	28	45	58	11.4	444	710	42	
42	31	50	64	12.0	492	830	47	
44	36	58	73	12.5	534	960	52	23(32)
46	40	64	81	13.1	590	1110	57	
48	44	71	90	13.8	650	1250	63	
50	49	78	99	14.3	700	1420	69	29(41)
51.5	52	83	106	14.7	736	1560	73	
54	59	95	121	15.4	810	1800	81	
56	64	103	130	16.3	910	2100	88	37(52)
59.5	73	116	148	17.0	985	2500	101	
>64	>80	>128	>164	18	~	~	~	45(−)

26

Weather of the Middle Latitudes

26.1. Introduction. The middle latitudes of the northern hemisphere, lying between tropical and polar regions, have a temperate climate that is favorable to man.

There are more people in the mid-latitudes, and there is more "weather." Weather patterns in the tropics and in polar regions tend to occur in more or less dependable patterns, which is not the case in the middle latitudes.

In the region of the middle latitudes masses of air moving northward from the tropics and southward from polar regions tend to converge and create various types of weather fronts. The reaction of these air masses with each other and with the land and water surfaces of the earth causes the constant weather changes which characterize the middle latitudes of both hemispheres. Widespread areas of low- and high-pressure drift eastward in the prevailing westerlies of these latitudes, alternately bringing changes in weather conditions.

This chapter deals with the air masses, fronts, and high- and low-pressure systems of the middle latitudes. The preparation and use of weather maps are described, and general principles for forecasting weather from surface weather maps and from local indications are given. In addition to the surface weather maps, professional meteorologists construct and use many other maps, charts, and graphs which show pressure, humidity, temperature, and wind conditions in the upper portions of the atmosphere. These data are used in forecasting and in aircraft operation. The recent development of new instruments and techniques for gathering and interpreting atmospheric conditions at various elevations above the earth's surface has enabled the meteorologist to gain a better understanding of present weather conditions and to forecast changes more effectively than would be possible with only the use of the surface weather map.

26.2. The Meaning and Classification of Air Masses. An air mass is a large body of air whose physical properties, particularly temperature and moisture distribution, are nearly homogeneous in the horizontal. One of the most important elements of forecasting is recognizing the various air masses in the weather picture, determining their characteristics, and predicting their behavior.

When a large body of air remains for some time over a locality, it acquires the characteristics of that region. For example, air that stands for several days or weeks over northern Canada during the winter becomes cold. It will

have low moisture content, both because of its coldness and because of the absence of water at the earth's surface from which vapor could be received. It would be described as a cold, dry mass of polar continental air, and the region where it acquired those characteristics is known as the source region (Fig. 26.1). On the other hand, a body of air which stagnates over the Gulf of Mexico for some time acquires the warmth of those waters, and it will acquire a large content of water vapor because of the ready evaporation induced by

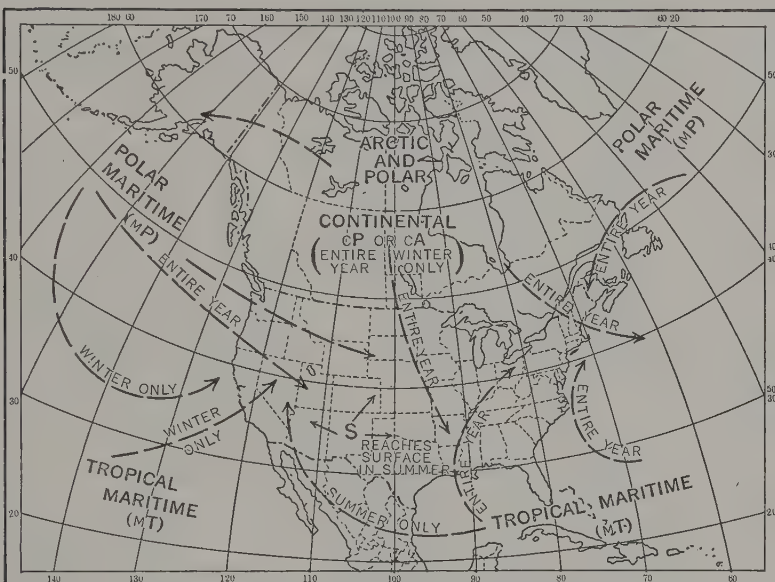


FIG. 26.1 AIR MASS TYPES THAT VISIT THE UNITED STATES. *Courtesy CAA*

the large capacity of warm air for vapor. Such a body of air would be known as a warm, moist mass of tropical air. In this case the source region, the Gulf of Mexico, is tropical maritime.

Air masses are classified according to their sources, which may be arctic, polar, tropical, equatorial, or monsoon. They are further classified as to their moisture content. Masses whose source regions are over the ocean are known as maritime air masses and are moist or high in water vapor content. Those originating over land areas are known as continental masses and are relatively dry or low in water vapor content. A further classification depends on whether an air mass, once it starts to move about, is warmer or colder than the surface over which it is moving. For example, a mass which moves northward over the Gulf states from the Gulf of Mexico would be classed as a warm mass in winter because land surfaces of those states in winter are colder than the waters of the Gulf. However, in summer the mass would be classed as cold because then the land surfaces are warmer than the water surfaces.

26.3. Weather in Warm and Cold Air Masses. Warm and cold air masses may occur in either summer or winter months. Weather associated with these air masses is a function of the temperature differential between the air mass and the underlying surface. A cold air mass will absorb heat and moisture from below, the lapse rate will steepen, and heat and moisture will be conducted to higher levels. The typical weather associated with a cold air mass is good visibility, turbulent and gusty winds, cumuliform clouds, showers and, in severe cases, thunderstorms. Conversely, a warm air mass will surrender heat to the surface, and the coldest air is found in the layers near the ground or water. This stable stratification means that there is no tendency for the air to rise and mix, and the associated weather consists of layer-type clouds, fog, drizzle, poor visibilities, and steady or calm winds.

26.4. Oceans, Ocean Currents and Weather. The oceans and their currents have a very strong stabilizing influence on temperatures over most of the world. The oceans can stabilize temperatures because of the favorable heating qualities of water, pointed out in Section 23.17.

The moderating influences of the oceans are carried around the world by air masses and ocean currents. Figure 26.2 shows the general pattern of ocean currents throughout the world. Comparison with Figures 23.14 and 23.15 show that the direction of flow of ocean currents tends to coincide with the prevailing winds of the world.

Ocean currents distribute huge quantities of warm and cold water over thousands of miles. The warm currents prevent the great north-south temperature contrasts we would have otherwise. In the North Atlantic, the Gulf Stream is a predominant feature. Its cold counterpart is the Labrador Current, which starts in the Arctic Ocean, and passes south and southeastward past the Grand Banks, thence to the mid-Atlantic states of the United States. In the North Pacific, the current system is quite similar. The Japan Current brings warm water toward the Gulf of Alaska, and there is a cool current along the east coast of Asia. In the Southern Hemisphere, the cold polar current is mainly from east to west, although there are numerous branches along the west coasts of South Africa and South America. The general effect in the northern hemisphere is to have cold east coasts, warm west coasts north of 40°N, warm east coasts, cool west coasts south of this latitude.

The Gulf Stream illustrates how ocean currents affect weather and climate. It flows through the Straits of Florida, where it unites with the Antilles Current. The combined current flows northward at three to four knots along the Atlantic coast, then up to Nova Scotia and Newfoundland. The Gulf Stream air masses usually do not penetrate the East Coast because of the prevailing westerly winds, but the warm waters of the Gulf Stream serve as an active breeding ground for many of the severe storms which cause heavy rains, snows, and strong winds over the Seaboard states. Also, the Gulf Stream serves as a path for many hurricanes.

At the Grand Banks of Newfoundland, where the Gulf Stream meets the

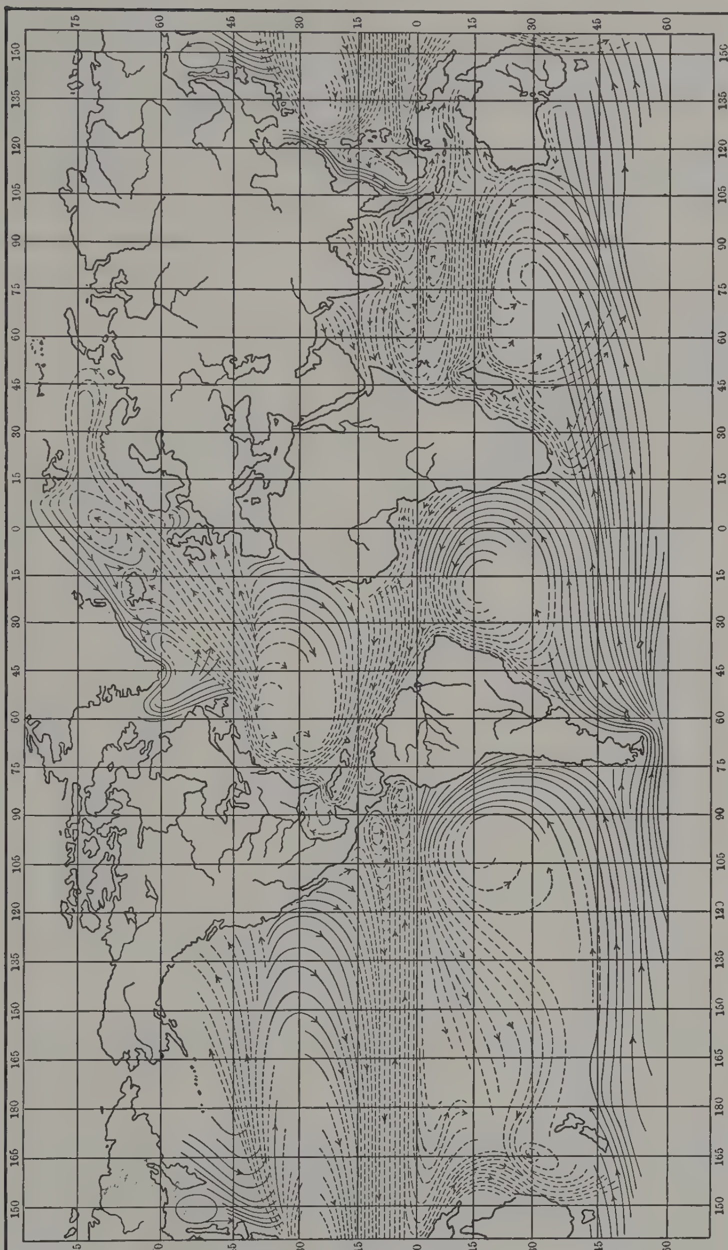


FIG. 26.2 OCEAN CURRENTS—COLD, SOLID LINES; WARM, DOTTED LINES. Courtesy U.S. Weather Bureau

cold Labrador Current, the world-famous fogs occur. Soon after this, the Gulf Stream current divides into several branches. One flows toward the west coast of Greenland, where it greatly modifies the climate of the southwest coast—so much so that Eric the Red led his fellow Norsemen there to settle. Another branch flows toward Iceland, where it mellows the climate somewhat before losing itself in the Norwegian Sea. The main branch of the Gulf Stream passes straight eastward, dividing again soon. The southern branch turns southeastward, skirting the coasts of southwest Europe and Africa as a cold current before returning to the tropics to start the long journey over again. The northern division of the current, hurried along by the strong winds of the Icelandic Low, washes the shores of west and northwest Europe with the warmest waters to be found anywhere at latitudes this high. The current goes into the North Sea and along the west coast of Norway, contributing a strong mellowing influence on Norway's climate, and throwing off eddies of warm water into the Norwegian Sea to influence the weather there. The current then goes past North Cape as far as Murmansk, so famous in World War II as an ice-free port. One branch of the current keeps the west coast of Spitzbergen ice-free in summer, a coast only 800 miles from the North Pole. Even after the current sinks below the fresher waters of the Arctic Sea, it still provides enough heat through the ice to make the area much warmer than comparable Antarctic latitudes.

26.5. Fronts. Adjacent air masses with different qualities as to temperature and humidity do not tend to mix readily. The cold masses are heavy and the warm masses light, so the warmer of two converging currents tends to overrun the colder. It will be recalled that the polar front is the surface between the converging southwesterly winds of middle latitudes and the prevailing northeasterlies of polar regions. The latter form a wedge over which the winds from the south ascend. A frontal surface, then, is the boundary between two masses of air of dissimilar properties. A surface front is the area where this boundary intersects the ground. In general, there are three kinds of fronts: cold, warm, and occluded. All types are watched closely on weather maps because it is along them that the poorest weather conditions occur, and frequent and rapid changes from one type of weather to another take place in their vicinity.

26.6. Warm Fronts. Figure 26.3 shows a west-east, vertical cross section through the atmosphere. To the right is a mass of cool air which is flowing from the southeast; on the left is a warm air mass flowing from the southwest. As the currents are converging, the warm stream is forced to ascend the cool barrier. It is assumed that the system as a whole is drifting from west to east, as is customary for atmospheric disturbances in the temperate zone of middle latitudes. It is further assumed that the warm current has a reasonably high relative humidity. The slope of the wedge is exaggerated in the figure in order to show clearly the processes involved. Actually the ratio of slopes of warm fronts averages about 1 mile in the vertical to 100 miles horizontally, but will

sometimes be as high as 1 to 300. As the warm air stream rises over the wedge of cold air, it expands and cools adiabatically, which results in the formation of the various cloud types shown.

The figure shows a situation which is quite typical of warm fronts that occur in the United States and other portions of the middle latitudes. Warm front areas often cover hundreds of square miles—in fact, whole states or groups of states. Cloud ceilings are low because of the presence of nimbostratus clouds over wide areas, and visibilities may be poor due to the presence of rain or drizzle and fog. Where temperatures in the cloud and rain areas are near freezing, icing on aircraft is prevalent.

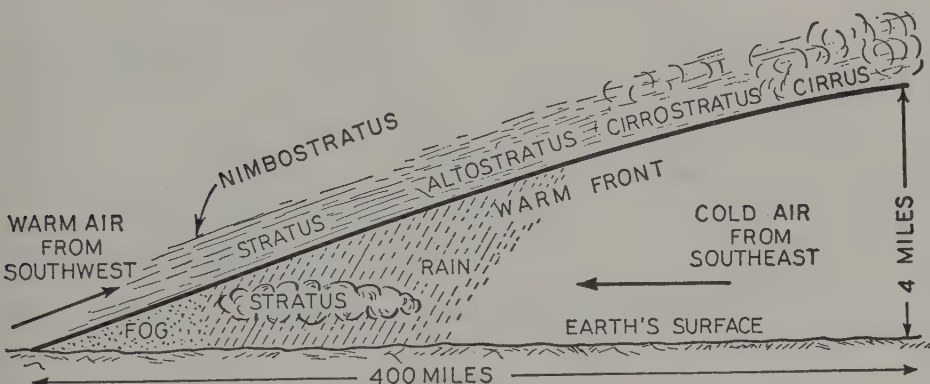


FIG. 26.3 TEMPERATURE, CLOUD, AND PRECIPITATION PHENOMENA

Warm front flying is generally smooth, except when unstable warm air is involved. In this case, thunderstorms and other turbulent clouds will form in the warm air above the frontal surface. In fact, any cloud type may appear along a warm front under various conditions. During late fall and early spring, frozen rain (sleet) may form in the rain curtain under the front when raindrops falling from above are frozen in the cold air of the wedge.

26.7. Cold Fronts. A west-east, vertical cross section through the atmosphere showing a typical cold front of the middle latitudes appears in Fig. 26.4. At the left in the figure is shown a wedge of cold air advancing from the northwest. It is underrunning and forcing upward a stream of warm, moist air that flows from the southwest. The system is drifting toward the east. As in the illustration of the warm front, the wedge is exaggerated so that the principles involved will stand out clearly. Cold fronts are usually steeper than warm fronts, with slopes ranging from 1/50 to 1/150. Even when the slopes are similar to those of warm fronts, the leading edge of the cold front is much steeper because of the effect of surface friction on the advancing cold air.

As in the case of the warm front, weather is poor along the cold front, but it is a different type of weather, because the greater steepness of the cold front makes it act more violently in forcing the warm air upward, with resulting

formation of clouds and precipitation. Warm air is nosed upward by the leading edge of the cold wedge, and cumulus rather than stratus clouds form. The cloud tops commonly reach quite high and often develop into cumulonimbus. Precipitation types are rain showers and often heavy hail or snow flurries. Cold-front cloud and precipitation areas are narrow horizontally as compared with those of the warm front. The air is usually rough up to an elevation of 6000 feet, and it may be turbulent to heights of 20,000 feet or more when thunderstorms are present, which is quite common. At levels where the temperature is at or below freezing, aircraft icing will be encountered, and visibilities and ceilings are unfavorable for contact flight in the cloud and precipitation region.

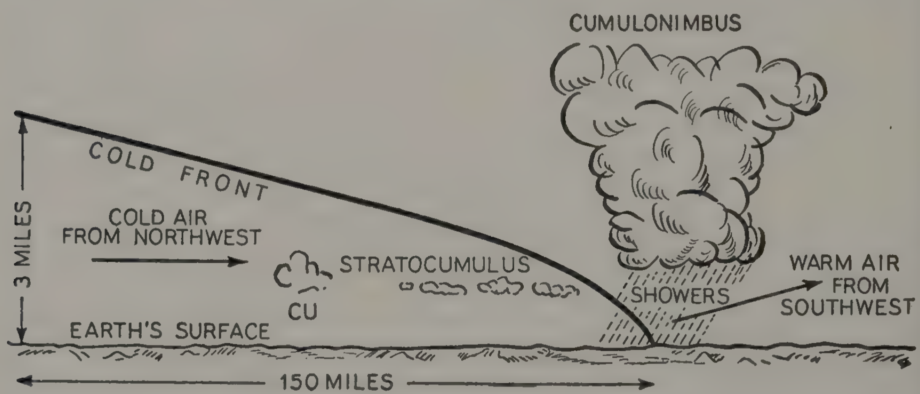


FIG. 26.4 COLD FRONT WIND, TEMPERATURE, CLOUD, AND PRECIPITATION PHENOMENA

In the cold air immediately behind the front, stratocumulus or cumulus clouds often prevail over mountainous or moist areas. They form as the cold air moves rapidly over ground previously heated by the presence of the warm air ahead of the front.

Before considering occluded fronts let us examine an extra-tropical cyclone and note the relationships which exist between various kinds of air masses and fronts which may be found in an extra-tropical cyclone, or low.

26.8. Extra-Tropical Cyclones. Figure 26.5 shows the air masses, fronts, clouds, precipitation, and winds which are a part of an extra-tropical cyclone, also known as a depression, low-pressure area, or simply as a low. The figure represents an idealized model as visualized by the Norwegian meteorologist J. Bjerknes, and it shows the low in one particular stage of its development. The center sketch shows a plan view. At the top of the figure appears a vertical section of the low taken through the line A-B; the bottom diagram is a vertical section taken through the line C-D. Looking back at the plan view we note the warm front where warm air from the so-called warm sector is converging and ascending with cold air to the right. A cold front exists where cold air at the left is under-running air in the warm sector. A broken arrow pointing to

the right at the middle of the figure indicates that the entire formation, that is the low, is moving toward the right, or east. The shaded portion shows where rain is occurring. Cloud types are not shown in the plan view.

The vertical section through C-D, which is shown on the lower portion of the figure, helps to explain what is happening in the upper air. It will be noted that cumulonimbus clouds are shown at the cold front; altocumulus clouds also

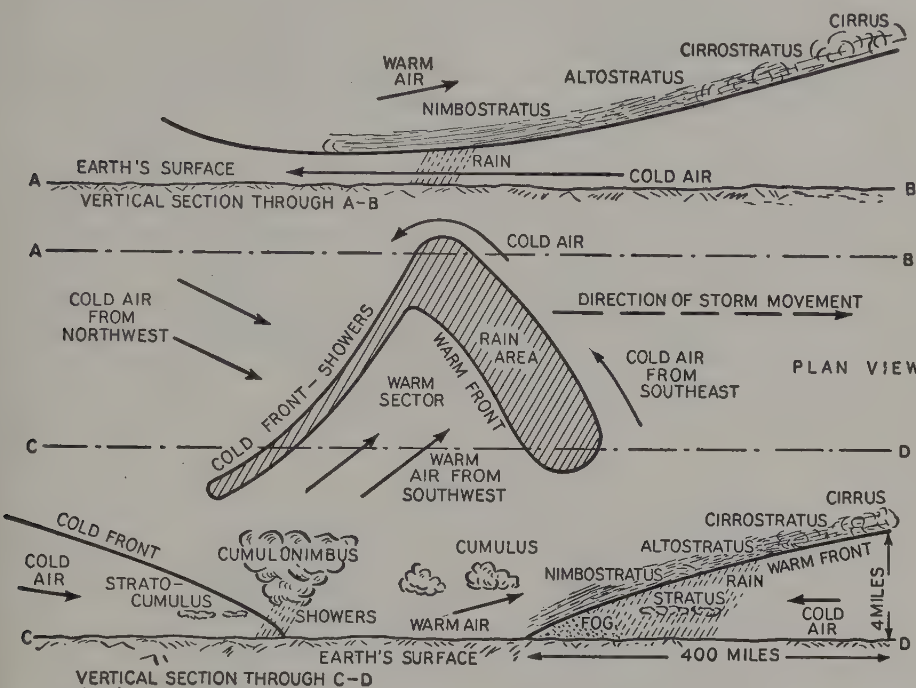


FIG. 26.5 A PLAN VIEW AND TWO VERTICAL SECTIONS OF AN EXTRA-TROPICAL CYCLONE. Hatched portions in the plan view show where rain is occurring. (*After Bjerknes*)

are often present there. In the cross section through A-B the warm air does not touch the earth's surface but is riding up over the cold air which is sweeping around toward the west. If we look back at the middle and lower views, the broad area of rain at the warm front and the narrow band of rain along the cold front are evident.

26.9. Formation and Occlusion of Extra-Tropical Cyclones. The life history of a depression is shown in Fig. 26.6. A stationary front such as the polar front is shown in *a* with cold air flowing toward the west while warm air flows toward the east. In *b* the front has ceased to be straight, possibly because pressure is being exerted at the left side of the figure by a mass of cold air to the north. A definite cold and warm frontal system has developed, and the arrows show that the wind has commenced to blow in a counterclockwise direction around a center of lower pressure. The hatched areas indicate

that cloudiness and precipitation have begun. This development is known as a wave that has formed along the stationary front, and the wave will move from left to right along the front in much the same manner as an ocean wave. The cyclone has reached a normal stage of development in *c*. The cold front advances faster than the warm front, and in *d* has overtaken the warm front

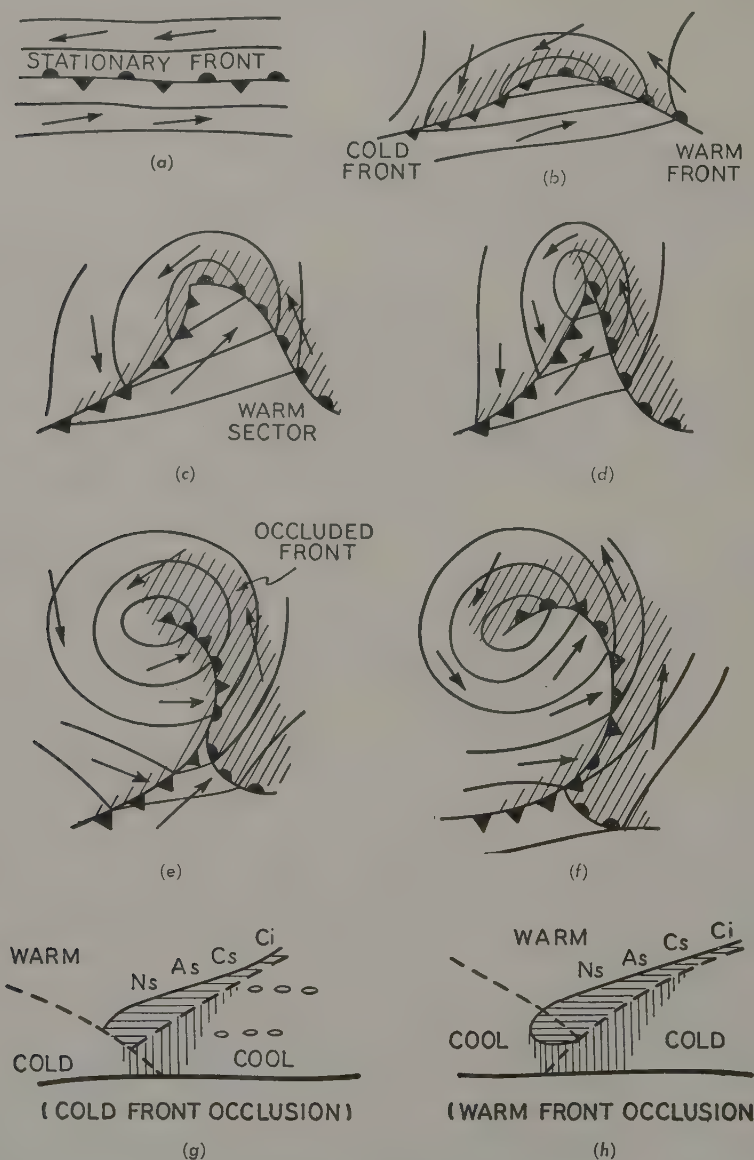


FIG. 26.6 DEVELOPMENT OF A DEPRESSION. Horizontal section, or plan view. Hatched areas are precipitation areas

in the vicinity of the center of the depression; the dying-out or occlusion of the cyclone has begun. The process from this stage onward resembles, in fluid motion, the breaking of an ocean wave. Further occlusion has taken place in *e* and *f*; under these conditions cloudiness and precipitation continue but in diminishing amounts. Occlusion, if it continues, results in the obliteration or filling up of the depression.

Two distinct types of occluded fronts are shown in *g* and *h*. When the cold front caught up with the warm front, the air in *g* to the left was colder than that at the right, and therefore it underran the latter as shown. The warm sector has been squeezed above the ground level. Precipitation continues at and behind the surface front, and it is chiefly that of the showery type such as is found along cold fronts. In *h*, which shows the warm-front type of occlusion, the air to the left is not as cold as that at the right. The cool air, therefore, is shown to be rising over the cold air, and precipitation continues at and ahead of the surface front; it is the steady rain or drizzle typical of warm fronts.

26.10. Extra-Tropical Cyclone Weather. Assume that the low shown in Figure 26.7 is moving east-northeast at 600 miles per day, and that the center

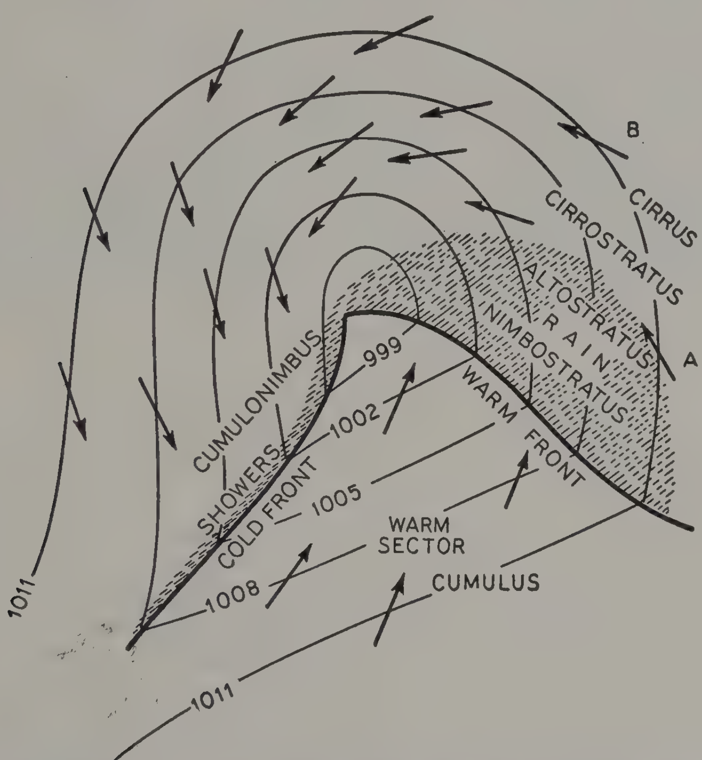


FIG. 26.7 EXTRA-TROPICAL CYCLONE. Rain or showers are occurring throughout the shaded area

passes north of the ship at Point A. The first indication of the approaching storm is a falling barometer, which will continue to fall, and more rapidly, until the warm front passes. Along with the pressure fall, cirrus clouds usually appear, and these thicken in a few hours to cirrostratus. If the overrunning air is unstable or turbulent, cirrocumulus will occur along with the cirrostratus, forming the "mackerel sky" so often mentioned in sailing-ship lore. Winds are southerly and increasing. The waves start to build up, along with the wind, and are superimposed on a southwesterly swell moving out from the area of the storm center.

When the warm front is about 300 miles away, altostratus clouds are predominant; sometimes they are mixed with altocumulus. Precipitation, rain or snow, can start at any time when the warm front is 200–300 miles distant. Winds and waves continue to increase, with the winds backing more and more into the southeast. After the precipitation starts the rain or snow becomes heavier, the clouds thicker and lower (becoming nimbostratus, and sometimes stratocumulus). Often, there is low stratus or fog when falling rain saturates the cold air underneath the front, and there may be cumulonimbus clouds above the front. Winds and waves continue to build, winds up to 45 knots in a strong storm, and waves 25 to 35 feet with an occasional high one up to 50 feet.

As the warm front passes, the winds shift from southeast to southwest; the temperature rises rapidly; cloudiness decreases or vanishes altogether; precipitation stops; the barometer steadies and remains so through the warm sector. Winds will usually be lighter and seas lower.

As the cold front approaches, the southerly wind flow increases and high cumuliform clouds will darken the horizon to the west and northwest. When the front arrives, there are heavy showers, often thunderstorms, strong gusty winds, and confused seas. The wind shifts sharply from south or southwest to a direction between west and north; the barometer rises rapidly; the temperature drops sharply. Usually, there is rapid clearing behind the cold front. Waves will now come from the northwest and increase rapidly—sometimes up to 35 feet in six hours. The seas will then subside gradually, although it will sometimes be two days before they drop below 10 feet.

Let us suppose now that we were located at point *B* and that the low center will pass to the south of us. Figure 26.7 shows that Point *B* will not encounter the warm and cold fronts, so that the weather sequence will be quite different from that at Point *A*. The first indications of the approach of the low are cirrus clouds, a shift in wind direction to the east, and a downward trend of the barometer. As the low moves closer, cirrostratus clouds replace the cirrus, the wind continues from the east, and the barometer continues downward. Presently altostratus clouds replace cirrostratus clouds, and steady, light rain begins; the wind continues from the east; the barometer falls further. As the low progresses east-northeastward, the wind shifts to northeast and then to north, with nimbostratus clouds replacing the altostratus. Eventually the wind

shifts to northwest; the barometer begins to rise; the sky gradually clears; the precipitation ceases. The low has passed to the eastward, and fine, clear weather prevails.

The description above is of an idealized low. Actually, lows vary as much as people do. Some are of large diameter, well over 1000 miles; some are small, 400 to 500 miles. Some have heavy precipitation; others have little. Cloud forms may not follow the conventional pattern. However, wind, temperature, and pressure nearly always follow a predictable pattern, particularly at sea.

FIG. 26.8 COLD FRONT CLOUD. *Official U.S. Navy Photograph*

26.11. Distribution and Movement of Lows. Extra-tropical cyclones (lows) form along fronts, hence occur with greatest frequency in the higher mid-latitudes where the cold and warm air masses meet along the Polar and Arctic fronts. In the Northern Hemisphere, there is a maximum frequency of lows at 50°N in winter, 60°N in summer. In the Pacific, there is a broad band of frequent cyclone activity from southeast Asia to the Gulf of Alaska. In the cold season, these storms become very intense, and usually move northeastward to accumulate in the Gulf of Alaska. Some storms which form on the mid-Pacific polar front take a more southerly track and reach the coast as far south as Southern California.

On the Atlantic side, the most favored region for low development is the Virginia Coast and general area east of the southern Appalachians. These, often called Hatteras Storms, are frequently very intense. They move north-

easterly along the Gulf Stream and eventually stagnate near Iceland, or in the waters between Greenland and Labrador.

Figure 27.1 shows preferred tracks of mid-latitude lows.

The rate of movement in summer is about 500 miles per day; in winter it is somewhat faster, probably averaging 700 miles in 24 hours, but there are many variations. At times an extra-tropical cyclone may slow down and remain stationary over an area, while at other times a section of the country may be subjected to a series of lows which move along quickly one after the other. They are more stormy and sharply defined in winter than in summer.

26.12. Anticyclones. Anticyclones (Fig. 26.9) are areas of high pressure; their name is derived from the fact that the wind within them blows clockwise and outward, opposite to that of cyclones.

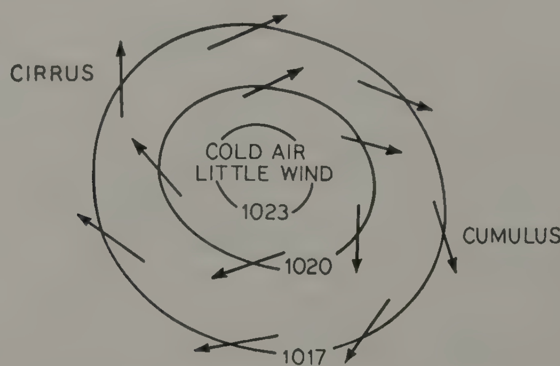


FIG. 26.9 AN ANTICYCLONE, HIGH, AND ASSOCIATED WEATHER ELEMENTS

The sub-tropical anti-cyclones, centered around the world at 30° latitude, are very persistent at all times of the year. They move little or not at all. The migratory anti-cyclones, or highs, alternate with lows in a regular parade across the oceans and across the United States. In North America, the likely regions for initial development of highs are Alaska and western Canada to the east of the Rocky Mountains. These highs move southeastward toward the Atlantic Coast, lose their identity as they reach the warm Atlantic waters and become absorbed in the subtropical anti-cyclone.

Cool or cold and fair weather is typical of highs.

Their rate of movement and size are fairly comparable to that of lows. Many highs which invade the United States may be thought of as atmospheric mountains of cold, dense air which have broken away from their northern source regions to drift southward in order to lessen the pressure which builds up in polar areas.

26.13. Preparation of Surface Weather Maps. Surface weather maps are prepared four or more times daily at forecasting centers. The technical methods involved are beyond the scope of this book, but enough has been presented to this point to enable the reader to understand and use an already prepared

surface chart. These charts are available in daily newspapers, and at sea they are available over several types of broadcasts. Some ships even plot their own weather charts.

Figure 26.10 shows a completed weather map that is typical of conditions during late spring over the central and eastern portions of the United States. On the particular day that this map was drawn, high pressure dominated the plains states. Areas of high pressure also prevailed east of New England and east of Florida. An area of low pressure that extended from the Mississippi Valley to the Atlantic seaboard dominated weather conditions throughout the entire eastern portion of the country. A cold front extended from northwestern Ohio to Louisiana, while a warm front ran through northern Ohio, southwestern Pennsylvania, and Virginia. A mass of cold continental polar air existed west of the cold front; cold maritime tropical air was in the warm sector of the low, i.e., between the cold and warm fronts; and maritime polar air was flowing in from the Atlantic Ocean east and north of the warm front. The highest pressure on the map was 1025.1 millibars at Concordia, Kansas; the lowest was 1011.9 millibars at Cleveland, Ohio.

A closer examination of the figure reveals that the high-pressure area in the middle west is associated with a clockwise circulation of wind that blows outward. Throughout much of the high, skies are clear and temperatures are cool. In the low-pressure area the wind is seen to be circulating in a counterclockwise manner and inward. Cloudy skies, precipitation, and higher temperatures prevail in the low. A broad area where it is raining is noted to the east and north of the warm front where maritime tropical air is converging with and ascending maritime polar air. The positions of these air masses, one above the other, are indicated by the air mass symbol found just east of Lake Huron.

It will be noted that in general the winds west of the cold front blow from the northwest, whereas those east of the cold front are from the southwest. Temperatures at places east of that front are, for the most part, higher than those to the west, and pressures to the east of it are falling while those to the west are rising. East and north of the warm front, pressures are falling, and the wind has an easterly component; south and west of the warm front, pressures are in general falling less rapidly, and winds blow from the south or southwest. Most places ahead of the warm front reported lower temperatures and dewpoints than those that prevailed behind the front.

It is apparent that the surface weather map does not show conditions that exist in the upper air, such as the direction and velocity of the wind at various heights, cloud levels, turbulence, regions where airplane icing may occur, air stability, temperature and humidity values, and other phenomena important to the forecaster and airplane pilot. Therefore, in addition to the surface map, auxiliary maps and diagrams are prepared. The most useful of these are the constant pressure charts, which depict conditions at several selected upper levels along a constant pressure surface. For example, the 500-millibar charts show wind, temperature, and humidity conditions along this pressure surface,

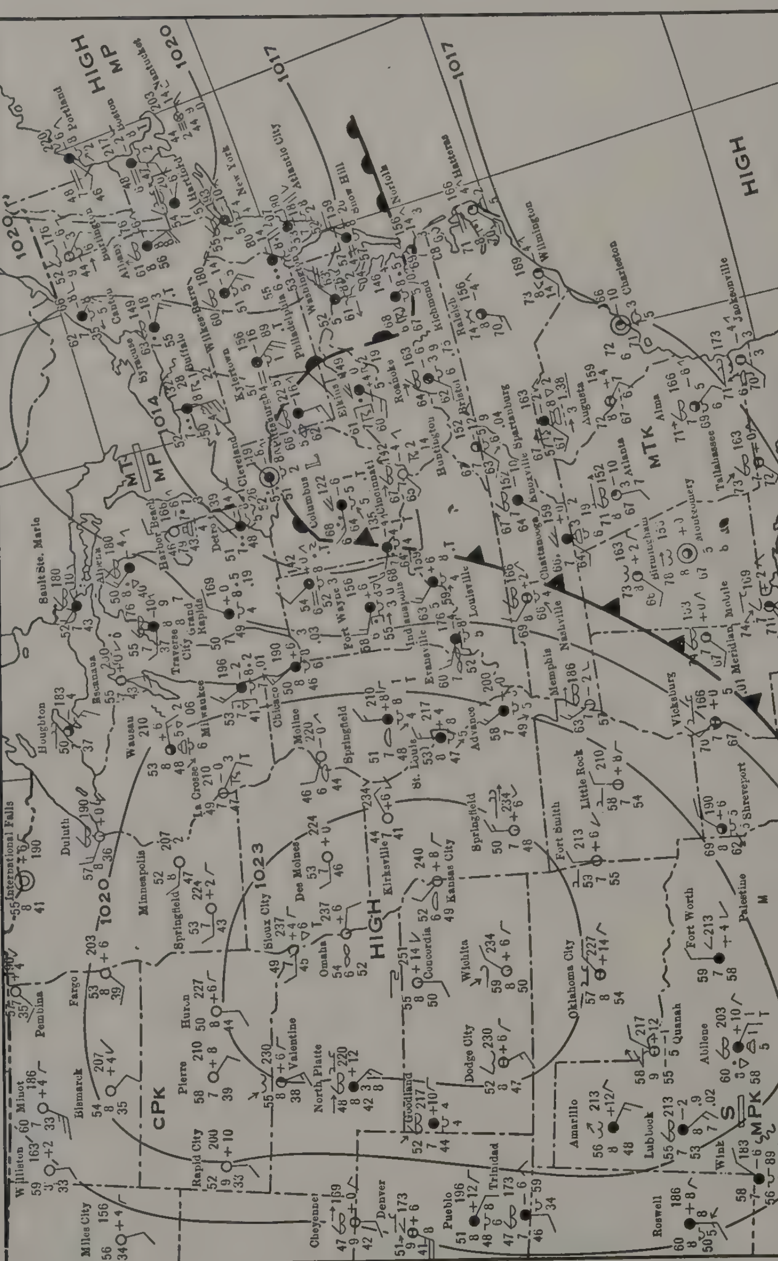


FIG. 26.10 A COMPLETED SURFACE WEATHER MAP

which varies between about 16,500 feet to 19,500 feet. The constant pressure charts are used in forecasting to determine movement of weather systems, wind flow at high levels, jet stream location and intensity, and the development and intensity of pressure systems.

Electronic computers will soon replace man on most hand plotting and analysis jobs. In the past decade, there has been rapid advance in the numerical forecasting field, and numerical upper air charts are now of a quality which can be equalled on a routine basis only by a few top analysts.

26.14. Preparation of a Forecast. Once all the weather charts are analyzed, the forecaster has several things to consider before he makes up a forecast. These include:

1. Displacement of fronts and pressure systems.
2. Deepening and filling of pressure systems.
3. Development of new pressure systems and their influence on the existing pattern.
4. Properties of existing air masses, and the changes which might occur with displacement.
5. Local influences, such as mountains, bodies of water, and industrial activity.

Formulas have been developed by meteorologists to solve the problems outlined above. Some of these are derived from theoretical studies which attempt to describe the state of the atmosphere in mathematical terms.

Empirical rules are derived from local observations. Climatological rules must be invoked, and finally the forecaster injects an experience factor.

26.15. Use of Weather Maps and Forecasting at Sea. The seaman can do much to help himself by using weather information, even if it is only what he can see or measure from his own bridge. Before radio came into use, the master of a ship had to rely on what conclusions he could draw from the appearance of the sky, movement of upper clouds, backing and veering of the wind, pressure changes, changes in the state of the sea, and changing visibility. Many seamen became, and are, relatively expert at forecasting weather changes relying simply upon their own observations; naturally, without knowing the state of the upstream weather, there are bound to be some disappointing results (they occur even when forecasters do know the upstream weather). Lacking other information, a seaman can improve upon his local knowledge by asking another ship or two in the general area to send position, present weather, barometric reading, and wind direction and force. With this, he can make a two- or three-point sketch, which will give him a rough estimate of the pressure pattern, intensity of the pressure systems in his area, and possibly, location of fronts.

Normally, ships can copy broadcasts which give them weather maps in coded form, as well as forecasts of weather conditions for the area of concern. Some ships are equipped with radio facsimile equipment, and can copy a great

variety of weather and oceanographic charts. Many ships construct their own weather maps by copying broadcast weather reports.

If a ship has forecasts available, it need not make its own, since the weather offices ashore have many more reports with which to work, and professional meteorologists to do the forecasting. However, there are many situations where a ship will be in an area which is not adequately covered, and it will be to the ship's advantage to use its own observation, a weather map, and to apply forecasting rules. Some of the more reliable rules are listed below:

1. Rule of persistence. This involves extrapolating into the future the same rates of movement and changes in intensity of pressure systems which have occurred in the past. The rule is quite reliable for up to six hours, with a gradual loss of reliability thereafter.
2. Troughs of low pressure tend to move to the position of the preceding ridge of high pressure in 24 hours.
3. Lows with a warm sector tend to move in a direction parallel to the warm sector isobars and with a speed of about 80 percent of the warm sector winds.
4. When a low has a large "open" warm sector, deepening may be expected.
5. Rate of deepening will usually increase with the narrowing of the warm sector (cold from approaching the warm front) and decrease when the occlusion process is going on.
6. When a low has nearly occluded, it moves less rapidly, and with very large occluded lows, the movement is very slow and irregular.
7. Small lows caught in the circulation of a large system tend to follow the main system.
8. A large low with no fronts will tend to move in the direction of the strongest winds in the circulation.
9. Frontal depressions tend to occur in families, each low following approximately the path of its predecessor but displaced somewhat towards a lower latitude.
10. Lows tend to move around large, warm highs in the direction of the air flow around their boundaries.
11. Occluded cyclones tend to weaken or fill, particularly over a relatively cool surface.
12. Ridges of high pressure between lows tend to move in the same direction and the same speed as the lows themselves.
13. Speed of fronts is determined largely by the wind component perpendicular to the front.
14. A front parallel to the isobars moves slowly or is stationary.
15. Frontal precipitation increases in intensity as the wind shift across the front becomes sharper.
16. Weather activity of cold fronts in subtropical latitudes is more active than in warm fronts. This condition is reversed in polar latitudes.

After the above rules have been applied, and the shipboard forecaster has developed an idea as to what the future weather map will look like, he is ready to make a forecast.

From his knowledge of the weather, gained by study and experience, the mariner uses his prognostic map and his own weather observations to determine future weather conditions. If there is a low approaching, the forecaster determines where the center will pass in relation to his own position and applies typical low-pressure center weather conditions as appropriate. Approaching cold and warm fronts are treated similarly. If the forecaster has temperature readings of air and water for the area, he can estimate the probability of fog occurrence. From the isobaric pattern, he can calculate wind speed and direction. These will provide the necessary information to make a forecast of sea state.

26.16. Weather Proverbs. Many weather sayings and proverbs that have been handed down through the years conform remarkably well with modern meteorological science. Those that are based on observations of elements such as wind, clouds, and pressure often work out well in sections where the sayings originated and in similar climatic areas. It is obvious, however, that many proverbs, while true in one locality, would be wholly inapplicable in foreign lands with different weather characteristics. The behavior of animals, birds, and fish is significant with respect to imminent weather changes, i.e., for periods of about one to twelve hours ahead. Their habits, however, are not related to the nature of a coming season. Such conditions as the storing of nuts and the thickness of fur are products of past seasons rather than indications of the weather of future months.

27

The Tropical Cyclone

The Tropical Cyclone

27.1. Introduction. Tropical cyclones are atmospheric systems, of tropical origin, in which the barometric pressure steadily decreases from the periphery to a minimum at the center, and where the winds spiral inward from all sides (counterclockwise in the Northern Hemisphere). When winds of the cyclonic circulation reach a strength of 64 knots or more near the center, the cyclone will, depending upon its location, be called a hurricane (Atlantic, Gulf of Mexico, Eastern Pacific), a typhoon (Western North Pacific), a baguio (Philippines), willy-willy (Western Australia), or simply a cyclone (Indian Ocean). Tropical storms are the same atmospheric phenomenon, but of lesser intensity —34 to 64 knots.

Mature tropical cyclones are extraordinarily violent. They usually do not involve as large an area as many temperate zone storms, nor do they have the sharply-concentrated, irresistible force of tornadoes. But, approximating the size of one and the intensity of the other, they are the most dangerous and destructive of all storms. From hurricanes alone, in an active season, damage may approach two billion dollars and hundreds, often thousands, of lives and homes are destroyed. Some coastal cities have been destroyed, never to be rebuilt.

Ships at sea must make every effort to avoid tropical cyclones of hurricane or typhoon intensity.

Even a well-found ship in some cases may be in danger of foundering. Masts and superstructures are vulnerable because of the extreme violence of wind and sea. Personnel may be lost overboard or injured by objects adrift. Lifeboats, airplanes, and other exposed objects are most certain to be carried away by the wind and sea. The prudent seaman will find it well worth while to study the nature of the tropical cyclone and to avoid it if possible. Many ships at sea have never encountered a tropical cyclone; if ordinary precautions are used, most ships should never have to pass through a violent one.

27.2. Areas Affected. Regions in which tropical cyclones form and move are shown in Fig. 27.1. Tracks are shown in the Pacific and Indian oceans both north and south of the equator and in the north Atlantic Ocean. It will be noted that in the Atlantic Ocean south of the equator the tropical cyclone is entirely absent. These storms are unknown in the Arctic and Antarctic oceans.

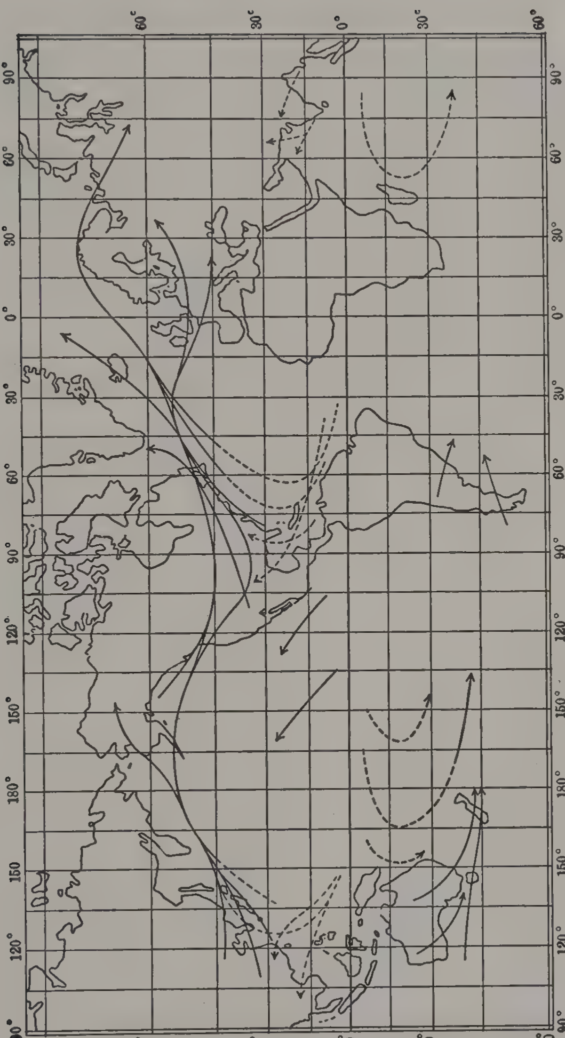


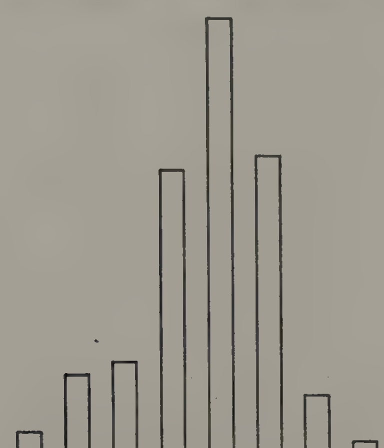
FIG. 27.1 PRINCIPAL STORM TRACKS OF THE WORLD. Solid lines, extra-tropical cyclones; dashed lines, tropical cyclones. Note that when tropical cyclones reach the higher latitudes in the North and South Pacific, and North Atlantic, they become extra-tropical cyclones as indicated by solid lines. (*From Pilot Chart of the Central American Waters*, October, 1946)

Tropical cyclones invariably form over the ocean near but only rarely, if ever, at the equator. Once formed they may travel distances of hundreds or even thousands of miles before losing their force and finally dissipating; they are the most persistent of all storms, sometimes living three to four weeks. Many tropical cyclones move near to or cross over continental coastal areas, but South America, Europe, and Africa are free from such visitations. In North America the east and west coasts of Mexico and the Central American countries and the states of the Gulf and Atlantic coasts may be affected. China, Japan, India, and the northwestern and northeastern portions of Australia are other regions subject to the tropical cyclone.

Tropical cyclones of the eastern North Pacific may be encountered from May through December off the western coasts of Mexico and Central America. Hurricanes of this region are as violent but usually not so large as those of the North Atlantic.

In the western North Pacific the tropical cyclone may occur during any month of the year, though the months of greatest frequency for this storm in that region are July, August, September, and October. There are over twice as many tropical cyclones per year in the Western Pacific as in the Atlantic, and more of these become giant storms.

27.3. Frequency of Tropical Cyclones. Tropical storms and hurricanes occur with greatest frequency during August, September, and October in the Atlantic. Figure 27.2 shows monthly frequency of a 78-year sample, excluding 2 tropical storms and 1 hurricane in February and March. Figure 27.3 shows the annual frequency of the same sample; the number per year is quite erratic, ranging from 1 to 21. This figure also shows that there was a maximum, on the average, in the early part of the period, then another starting in the early 1930's. The latter increased frequency has tended to maintain itself ever since, and there are more hurricanes. The average number of hurricanes during the 78-year period is 4, but it is 5 for the past 30 years, and 6 for the past 10 years. This increased number of tropical storms and hurricanes is associated with a gradual warming of the atmosphere during the period. There is now some evidence that the warming trend has slowed and it might be expected that the average



MONTH	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
NUMBER	10	40	45	141	217	146	28	4

FIG. 27.2 THE TOTAL NUMBER OF TROPICAL CYCLONES, INCLUDING HURRICANES, IN THE NORTH ATLANTIC IS SHOWN BY MONTHS FOR THE PERIOD 1886–1964

number of tropical cyclones will be less in the next few decades.

Tropical cyclones of the Bay of Bengal and the Arabian Sea are more likely to be encountered during May and October than in other months, whereas the season for tropical cyclones of the South Pacific and South Indian Ocean extends from September to May, with the months of January, February, and March having the greatest frequencies.

27.4. Formation of the Tropical Cyclone. It is fortunate that typhoons, hurricanes, and other tropical cyclones are comparatively few in number as compared with their non-tropical cousins. With the latter, there are often as many on the weather map in one day as there are hurricanes in a season or two.

Meteorologists have not been able to unravel the mysteries of tropical cyclone formation, although the tropical cyclone is the nearest thing to a simple heat engine to be found among atmospheric disturbances. Day after day, in tropical regions, conditions look just right for cyclones to form from existing disturbances in the trade wind belt—temperatures of air and water warm enough, plenty of moisture, winds of the right speed. Yet, only once in ten times are tropical cyclones born from these fertile-looking patterns, and when they do form the manner varies from storm to storm.

The mean latitude of storm formation moves poleward in the first half of the season and then retreats

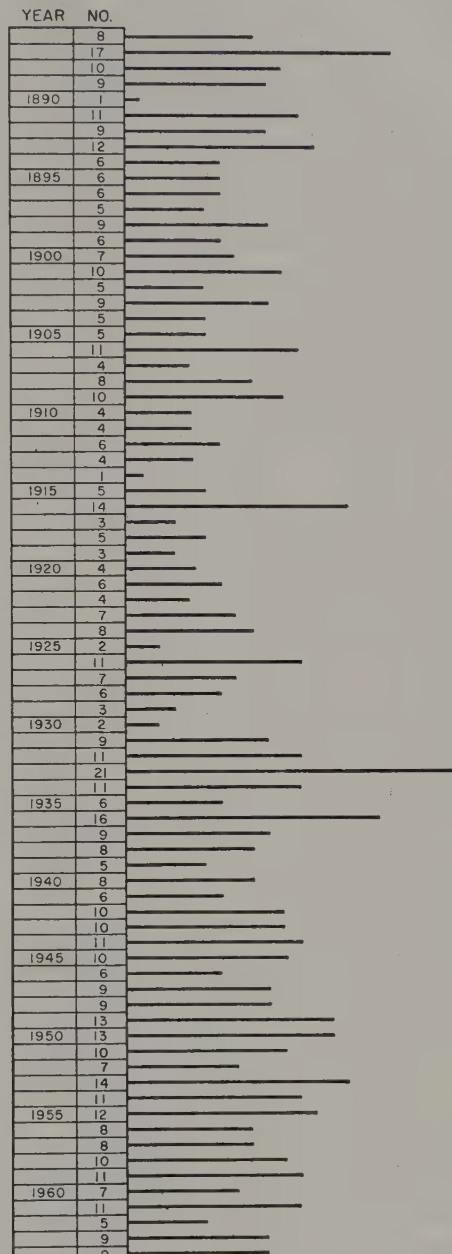


FIG. 27.3 TROPICAL STORM AND HURRICANE OCCURRENCES IN THE NORTH ATLANTIC FOR THE PERIOD 1886–1964

equatorward. Early- and late-season cyclones form mostly in the belt from 5° to 15° in the northern hemisphere, at the height of the season between 10° and 25°. In the Atlantic, there is some cyclogenesis between 25° and 30° N, with a northern limit of 35° N. The great majority of tropical cyclones undergo their principal development in the northeast trade wind current, and not in the doldrums or equatorial trough, as had been thought for so many years.

In addition to the north-south shift of tropical cyclone formation, there is an east-west pattern, particularly so in the Atlantic. Here, a majority of early season (May and June) storms originate in the Gulf of Mexico and western Caribbean. In July and August, the areas of most frequent origin shift eastward, and by September they are located over the large area from the Bahamas southeastward to the Lesser Antilles, and thence eastward to south of the Cape Verde Islands, near the coast of Africa. After mid-September, the principal areas of origin shift back to the western Caribbean and Gulf of Mexico.

27.5. Tropical Cyclone Movement. Tropical cyclones are notorious for their erratic movement. There is a general similarity of movement in the early stages of storm development along the ESE-WNW axis, and all cyclones have a tendency to move eventually toward higher latitudes. But, there is no longitudinal regularity in any turn to the north, and in all track samples there are benders, loopers, double loopers, and wobblers. Also, tropical cyclones have sudden accelerations (as much as 1500 percent in 24 hours), and sudden decelerations; sometimes storms stop suddenly and hold position within a 50-mile circle for as much as three days.

The mean speed of tropical cyclone movement south of 30° N varies, by areas, between 12 to 16 knots. Occasionally, when the sub-tropical highs are exceptionally strong, hurricanes and typhoons will move toward the west at 20 to 25 knots south of 30° N.

North of 30° N, speed of storm movement is much less predictable. The speed range is from 0 to 60 knots, and acceleration can be pronounced. Disastrous and unexpected results have occurred when hurricanes that were loafing along off the Virginia Capes have suddenly spurted and roared up the coast, sometimes at speeds as high as 70 knots.

Hurricanes and typhoons favor movement over the warmest waters. The Gulf Stream is a good example.

27.6. General Nature. The average mature tropical cyclone has an area of hurricane-force winds (64 knots or 75 mph) of a little over 100 miles in diameter, and gale-force (34 to 64 knots) winds over an area 400 miles in diameter. In large hurricanes, these areas may be over 200 miles for hurricane-force winds and 600 miles for gale-force. In a few huge Pacific typhoons, the area of hurricane-force winds has exceeded 300 miles, with gale-force winds covering an area over 1500 miles in diameter. The correlation between maximum winds at the center and the diameter of strong wind area is poor;

a gale-force wind 600 miles from the hurricane center does not necessarily mean that winds near the center will be of remarkably high speed. Small storms may be the strongest. For instance, the infamous Florida Keys hurricane in 1935, the most intense on record, had a path of destruction only 40 miles wide.

The strongest winds of hurricanes and typhoons have probably never been measured, because wind measuring devices are not designed to stand much more than 125 knots, after which they stop functioning or are blown away. Reconnaissance planes have often reported winds in the 130 to 150 knot (150 to 175 mph) range; actual measurements at land stations have been made as high as 150 knots; and in the Florida Keys hurricane mentioned above, engineers estimated that the winds must have been in the 170 to 215 (200 to 250 mph) range to account for the damage done. A feature of the winds which helps to account for much of the damage is their gustiness. Momentary gusts exceed the steady winds by 30 to 50 percent, so a wind of 100 knots may have momentary gusts to 150 knots.

Winds in a tropical cyclone do not blow in circles centered around the eye; instead, they angle in anywhere from 20 to 30 degrees all the way from the outer limits of the storm circulation up to the wall of the eye. The angle grows less and less as the eye is approached and the winds blow stronger. At the wall of the eye, the winds do blow in a circle. The 20 to 30 degree inflow accounts for the fact that birds, butterflies, and helpless ships may drift into the eye of a tropical cyclone.

It is typical for the strongest winds to occur to the right of the direction of motion, looking downstream. On the right side the forward motion of the storm is added to the observed wind velocity and on the left it is subtracted.

The steepest pressure gradients in the world, barring tornadoes, occur in tropical cyclones in lower latitudes. One ship in the Caribbean experienced a pressure fall of 1.34 inches (40.50 millibars) in 20 minutes. In the 1935 Florida Keys hurricane, one estimate gave a pressure gradient of 1 inch in 6 miles. The lowest sea-level barometric pressure readings for the whole world have been recorded in hurricanes and typhoons. The lowest reading at sea was 26.18 inches (886.56 millibars); the land record is 26.35 inches.

The eye of the tropical cyclone is unique among atmospheric phenomena. At the edge of the eye, the winds are at their strongest. Then, within a distance of as little as a few hundred feet, it is possible to have the winds fall off from 100 knots to 10. In the eye, the dense, dark clouds are gone, although there are usually some low clouds present. The average diameter of the wind eye is about 14 miles, but it can be as small as 4 miles and as large as 100.

The strong winds of tropical cyclones generate some of the highest of ocean waves. In an average hurricane, waves of 35 to 40 feet are common; in giant storms, they build to 45 to 50 feet, and there have been reports of waves 60 to 90 feet in height. The highest waves are found on the right side of the

storm along the direction of movement because the stronger winds are found here and they have a longer time in which to push upon the water, since waves and storm are moving in the same direction.

Waves move more slowly than the winds which create them, but still move much faster than the tropical cyclone itself. As the waves move out of the storm area, at perhaps 45 to 50 knots, they become swells and continue on ahead of the storm for hundreds or even thousands of miles. A characteristic of hurricane or typhoon swells is their long period of 2 to 4 per minute, as contrasted with the normal 10 to 15 per minute.

Rainfall is heavy in tropical cyclones. Over water, it has been calculated that there should be a fall of about 11 inches at any one location during the passage of a hurricane. Over land, because of the added lifting effect, tremendous amounts of rainfall are recorded, like the 49.13 inches in 24 hours at Paishih, Taiwan, or the 96.5 inches in 4 days in Jamaica.

Tropical cyclones live longer than any other storms. Their average life is 9 days, but many have lived 3 to 4 weeks, and the record-breaker logged 5 weeks during a grand tour from Africa to the Bahamas to Cape Hatteras to the Azores.

27.7. Hurricane Advisories and Storm Signals. During the hurricane season, the U.S. Navy, U.S. Weather Bureau, and the U.S. Air Force work together to provide the coastal areas of the United States and shipping interests with timely, storm warnings. The Weather Bureau is responsible for warning civil interests and merchant shipping, the Navy is concerned with its coastal activities and ships at sea, and the Air Force has the responsibility for Air Force and Army installations in the critical area.

The Navy and Air Force are assigned areas of reconnaissance responsibility and are frequently called upon to investigate areas of possible hurricane formation. Once a tropical storm is located, the hurricane hunter planes give it almost a 24-hour-per-day examination, sifting out all the facts on surface and upper winds, state of the sea, pressure, the eye and storm location. Without this reconnaissance information, the forecast centers would not be able to forecast any better than they did thirty years ago. Small storms would be missed for days or forever; intensities would be misjudged; movement forecasts would be very inaccurate. Hurricane recon is a difficult, dangerous job, but one that has saved many lives and prevented much damage.

A similar arrangement is in effect in the Pacific, except that typhoon warnings are issued for all civil and military interests from the Joint Typhoon Warning Center (Navy and Air Force), located in the Navy's Fleet Weather Central, Guam.

The hurricane warning system in operation furnishes timely warnings to most interested parties. Its development was made possible by recent advances in tropical meteorology, reconnaissance techniques, suitable aircraft, and highly developed navigation and communication equipment.

In addition to hurricane and storm communiqués by radio, a system of flags and lights (Fig. 27.4) is displayed at many coastal points along the United States seacoasts when winds dangerous to navigation are forecast for any coastal section. An explanation of the various warnings follow:

Small Craft Warning: One red pennant displayed by day and a red light over a white light at night indicate that winds up to 38 miles an hour (33 knots) and/or sea conditions dangerous to small craft are forecast for the area.

FIG. 27.4 STORM AND HURRICANE WIND DISPLAYS

Gale Warning: Two red pennants displayed by day and a white light above a red light at night indicate that winds ranging from 39 to 54 miles an hour (34 to 48 knots) are forecast for the area.

Whole Gale Warning: A single square red flag with a black center displayed during daytime and two red lights at night indicate that winds ranging from 55 to 73 miles an hour (48 to 63 knots) are forecast for the area.

Hurricane Warning: Two square red flags with black centers displayed by day and a white light between two red lights at night indicate that winds 74 miles an hour (64 knots) and above are forecast for the area.

27.8. Locating a Tropical Cyclone by Local Signs.

First Indications. The long-period, heavy swell of the hurricane arrives well before its clouds. The first clouds directly connected with the hurricane circulation are cumulonimbus (thunderstorm). There are active bands of these along a line several hundred miles ahead of the storm; the distance varies

with the size of the storm. Following these, and the day before the storm arrives, the tropical pattern is out of phase. The thunderstorms of the day before are missing. The usual cumulus clouds are suppressed. There are bright skies and above-normal temperatures. Then, the barometer starts to drop, and the wind may come from an unusual direction. Next day, the standard hurricane cloud pattern starts.

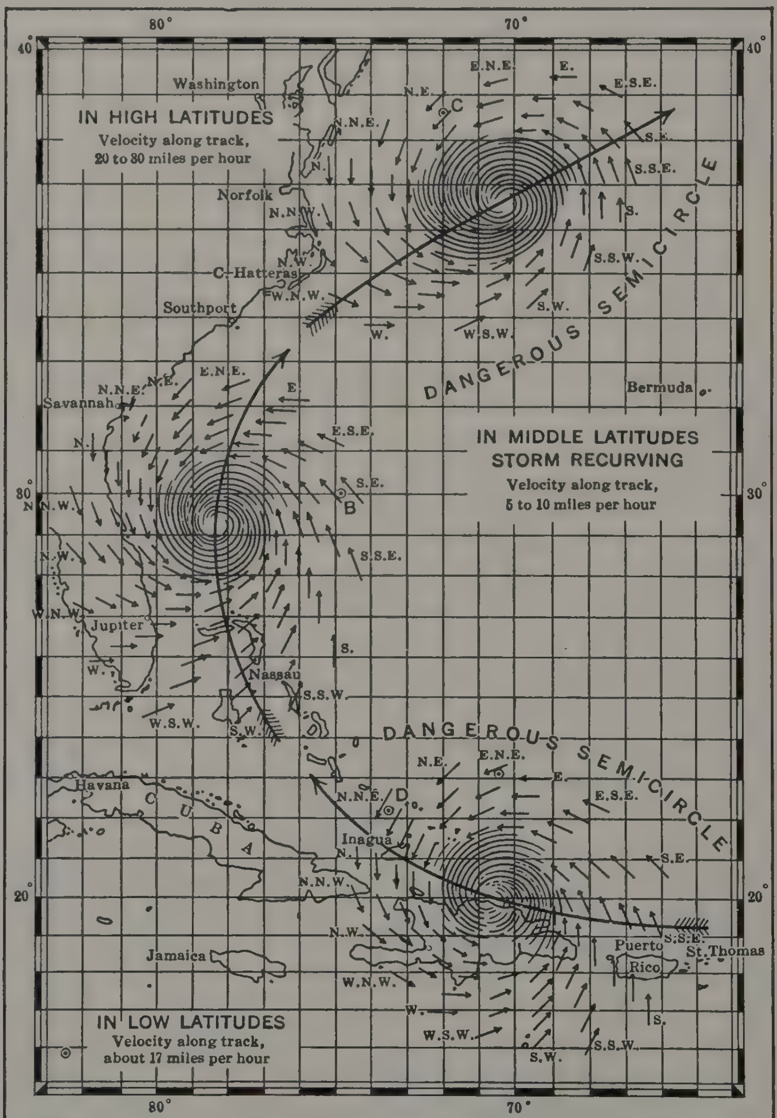


FIG. 27.5 CHARACTERISTIC PATH FOLLOWED BY TROPICAL CYCLONES OF THE NORTH ATLANTIC. (*From Pilot Chart of the Central American Waters, October, 1946*)

Convincing Signs. A drop in barometric pressure of 3.4 millibars (0.10 inches) or more within a 24-hour period, and particularly if it occurs over a period of 3 to 6 hours, is significant in relation to the approach of a tropical cyclone. It should be kept in mind in this connection that in the tropics there is a very regular, twice-daily rise and fall in barometric pressure over a range of 2 millibars (0.06 inches).

It is significant when there is an increase in wind speed of 25 percent or more in a limited area in the normal trade wind flow, especially if the wind flow changes cyclonically, say from easterly to a more northerly direction. Also, any wind south through west to north is a danger signal.

The significant cloud pattern starts with cirrus. These seem to converge in the direction from which the storm is approaching, a characteristic most noticeable at sunrise and sunset. The cirrus clouds are followed by cirrostratus, the producer of solar and lunar halos, and of brilliant ruby and crimson skies at sunrise and sunset. Next come the altostratus, often mixed with altocumulus. The steady rain accompanying the altostratus is another indication, as the rain in the tropics is usually the showery type. As the center gets closer, the clouds change at lower levels to cumulus congestus; the barometer falls more rapidly; the wind increases; the seas grow mountainous; finally, an ominous black wall of clouds approaches, called the "bar" of the storm.

27.9. Ships in a Hurricane. The following rules apply in handling ships at sea (see Chapter 10):

1. Determine the bearing, distance, and track of the storm from the official warnings, or from your own calculations if there are no warnings. From this information, you can plan how best to avoid the dangerous semicircle on the right side of the storm, looking downstream in the direction of movement. Relationship to shoal water must be considered in the planning.

2. If near a storm and have no warnings, determine bearing of the storm by a) direction from which swells are arriving and b) by adding 115° to the direction from which your observed true wind is blowing.

3. If the wind gradually hauls to the right (clockwise) the ship is in the dangerous semicircle. If it hauls to the left, you are in the safe or navigable semicircle.

4. If the wind remains steady in direction, increases in speed, and the barometer continues to fall, you are directly in the path of the storm.

5. Use your radar if available. A continuous knowledge of the center position is helpful in maneuvering.

6. Do not try to outrun or cross the "T" of a mature tropical cyclone; it usually means trouble. The main difficulty arises from the front-running swells, which build rapidly in size with the approach of the center. These can cut down ship speed by several knots, while the storm keeps roaring along, or speeds up.

7. If Sea Surface Temperature charts are available, avoid the areas of warmest waters. When tropical cyclones are moving slowly, at 10 knots or

less, they like such warm areas as a path. If the storms are moving fast, 16 knots or more, the warmer waters have little influence.

8. If the ship is actually caught in a storm circulation, even the fringes, these steps should be taken:

a. If you are dead ahead of the center, bring the wind on the starboard quarter (160° relative) and make best speed on this course. This will take the ship away from the center most quickly and into the safe semicircle.
b. If the ship is in the safe or navigable semicircle, bring the wind on the starboard quarter (130° relative) and make best speed.
c. If in the dangerous semicircle, bring the wind on the starboard bow (45° relative) and make as much headway as possible.

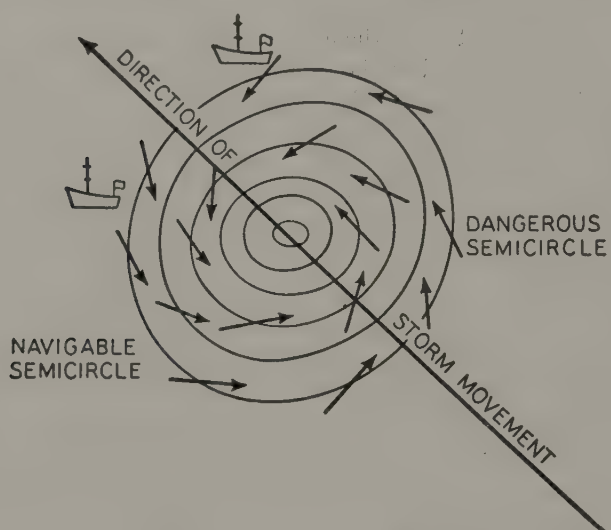


FIG. 27.6 A ship hove-to in the dangerous semicircle will note the wind to shift to the right (clockwise); the wind will shift to the left (counterclockwise) if the ship is in the navigable semicircle.

27.10. Sailing Ships (Northern Hemisphere). While making a preliminary study of the storm, sailing ships should be hove to on the starboard tack. If the wind shifts to the right, the ship is in the dangerous semicircle but on the proper tack. Then it may attempt to work away from the track of the storm center, close-hauled on the starboard tack. If necessary to heave to, do so on the same tack.

If the wind hauls to the left while hove to on the starboard tack, the ship is in the navigable semicircle and heading away from the track of the storm center. In this case the wind should be brought on the starboard quarter and then run as long as possible. If it is necessary to heave to, do so on the port tack; try to make as little headway as possible.

If the wind direction remains the same while hove to on the starboard tack and the barometer falls steadily, it is likely that the ship is ahead and in the path of the hurricane. This is true if we assume that the storm is circular in shape rather than elliptical. The ship should run with the wind on the starboard quarter and hold the compass course thus noted until the barometer begins to rise.

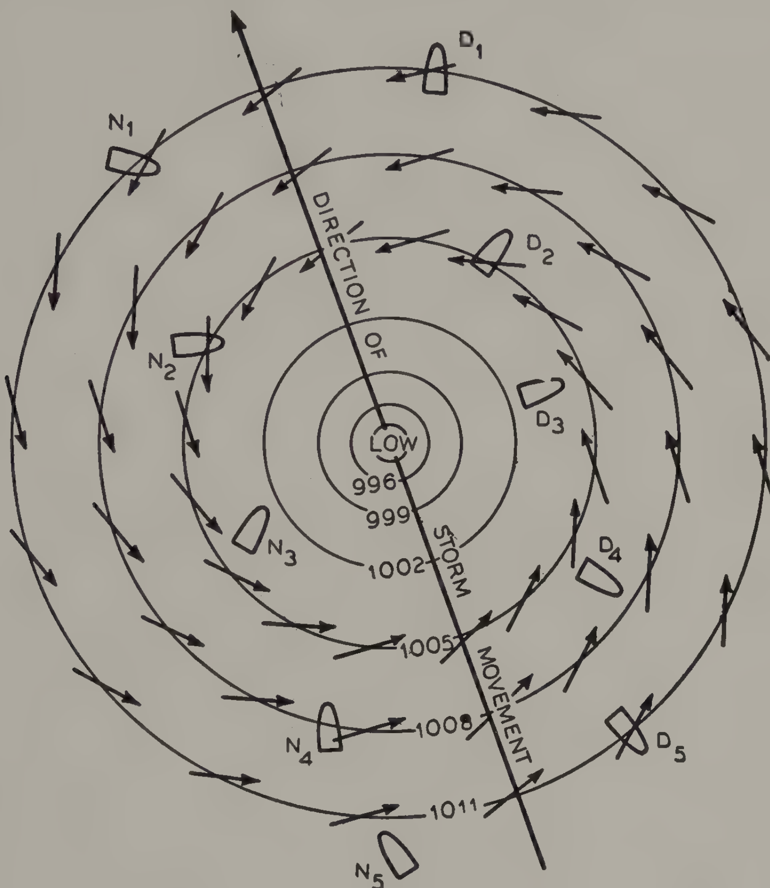


FIG. 27.7 This figure illustrates the rules for lying to by sailing ships in the northern hemisphere. Note that the wind draws aft in the cases of both vessels N and D.

APPENDICES

APPENDIX

1

Rope and Cordage

Ropes in common use are made of fiber and wire. Fiber ropes are called *lines* by most sailors.

A1.1. Fiber Rope. The following materials are used in the manufacture of fiber rope: manila, hemp, cotton, linen, sisal, henequen, jute, and man-made fibers, such as nylon, dacron, and polypropylene. The ropes commonly used on shipboard are:

1. *Manila, Made from Abacá.* Manila rope is made from the fiber of the abacá plant. The abacá is a perennial plant, growing to a height of from 10 to 20 feet.

When ready for harvesting, the matured abacá plants are felled and the stalks are then cut into thin slabs called "tuxies." Fiber extraction is then done by stripping the "tuxies" by mechanical means.

The fibers are combed smooth and straight by machines. At this stage, an emulsion of oils is added to soften and lubricate them. From 10 to 15 percent by weight of the finished rope consists of oil, making for preservation against both excessive dampness and excessive heat.

The combed fibers are spun into twisted yarns, wound on bobbins. The yarns are then twisted into strands by means of the bobbins and capstans. Three or four strands, each strand composed of a number of yarns twisted together, go to make the finished rope. This is accomplished in the laying machine. To counteract the tendency to unlay, the successive twists are taken in opposite directions, yarns being usually twisted to the right.

Rope is commonly made with three strands, but four are sometimes used. Also left-laid rope may be produced by reversing the direction of the twists. For special uses three ropes are sometimes twisted into a *cable* to provide greater elasticity.

2. *Hemp, Made from True Hemp.* Hemp rope is made of fibers from the stalk of the hemp plant, which is cultivated extensively in many parts of the world.

Hemp rope is now seldom used, but when used it is almost invariably tarred. The tar preserves the rope from deterioration due to dampness but reduces its strength and flexibility. At present tarred hemp is used only for "small stuff": ratline, marline, houseline, spun yarn, roundline, and seizing stuff.

3. *Cotton, Made from Cotton.* Cotton ropes are used principally for lead lines, taffrail log lines, and signal halyards.

4. *Synthetic Rope* (Fig. A1.1). From the long list of man-made synthetic fibers, nylon, dacron and polypropylene are the best for synthetic rope. The tensile strength of these fibers is approximately twice that of manila for a given size. They are resistant to rot, decay and marine fungus, and they have

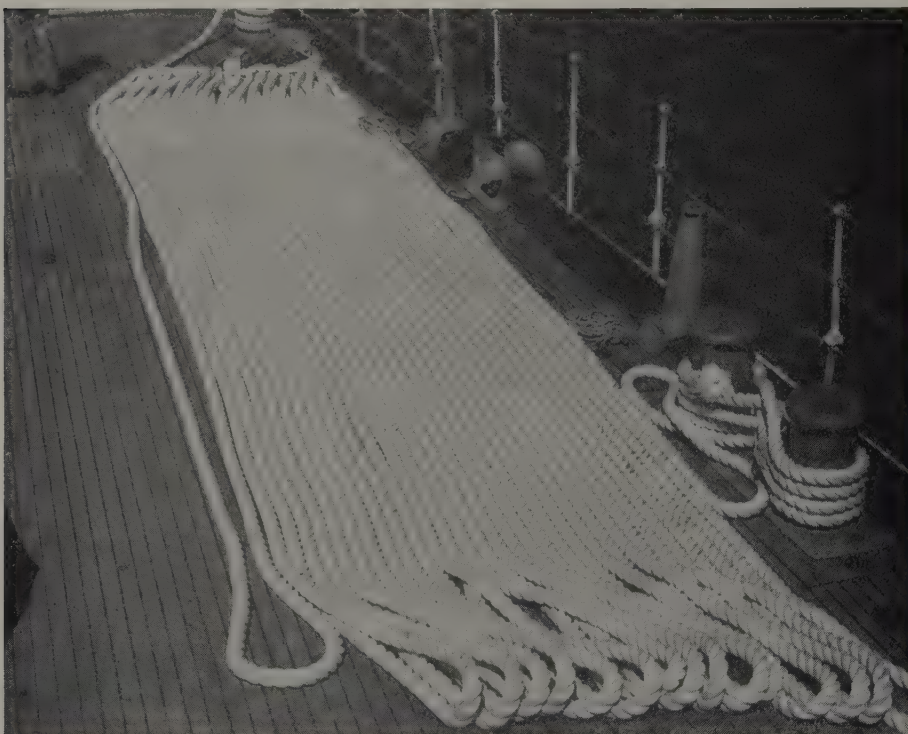


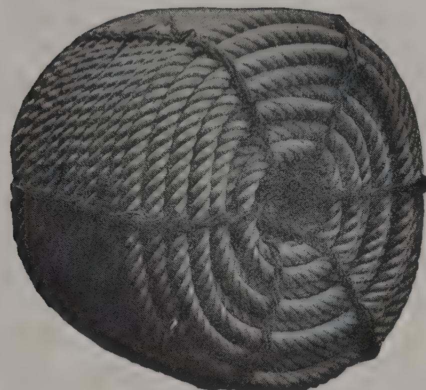
FIG. A1.1 EIGHT-INCH NYLON HAWSER FAKED DOWN. *Official U.S. Coast Guard Photograph*

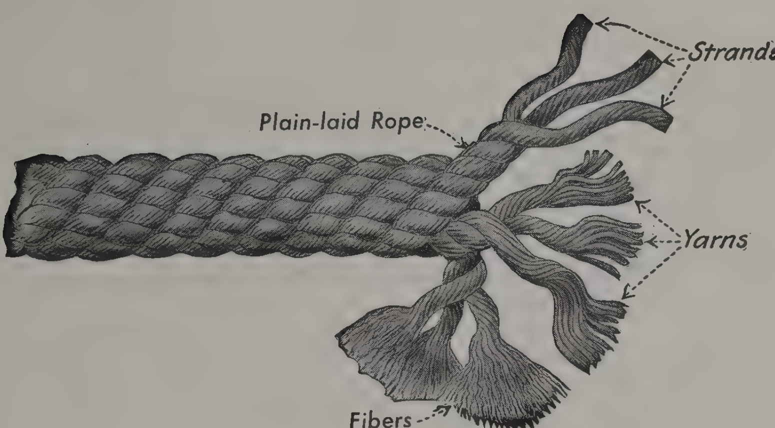
a low water absorption rate. Nylon and dacron stretch, absorb shocks, and return to normal length when strain is removed. Synthetic fibers are lighter in weight, less bulky, more flexible and are easier to handle and to stow.

Like manila or wire rope, nylon lines will part when weakened, when subjected to greater strains than they can withstand, or when given improper handling. Nylon lines can also be expected to part when stretched more than 40 percent of the length in use. The terrific backlash resulting from the parting of nylon line can cause serious injury.

A double braided type of nylon rope (Fig. A1.2) is approved by the Bureau of Ships as satisfactory for use on the same basis as regular lay 3-strand nylon rope. The double-braided type provides for better gripping surface for man-handling of lines. Cable-laid nylon rope (Fig. A1.2) and double-braided


(A) Double-braided Nylon Rope


(B) Rope in Coil



(C) Cable-laid Rope

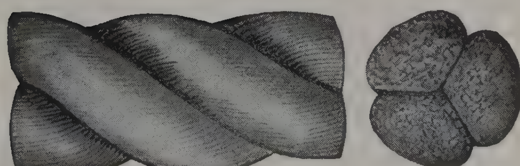

(D) Cross Section, 3-Strand Rope

FIG. A1.2 FIBER ROPE

nylon rope should be used for single part handling where a load is free to rotate. Plain-laid, 3-strand nylon rope (Fig. A1.2) should never be used in a single part to haul or hoist a load which is free to rotate.

A1.2. Fiber Rope. Fiber rope is designated as to size by its circumference and runs from about ⅝ inch to 16 inches and even more. However, the largest sizes are never seen on shipboard, 12 inches being about the maximum that even the largest ship would carry. The length is measured in fathoms; for shipment, it is made up in coils. (Fig. A1.2)

A1.3. Care of Fiber Rope. Unlike metal, fiber has not a permanent elastic limit within which it can be worked indefinitely. Therefore, no attempt should be made to put a maximum strain on a rope which has seen continuous service under a moderate strain or on one which has once been close to the breaking point. The safety of a rope decreases comparatively rapidly with use, dependent to some extent upon the amount of strain. This is due to the fact that the fibers slip a small amount under each strain in spite of the twisting.

Rope tends to contract when wet, and, unless allowed to do so freely, may be injuriously strained. It is for this reason that running gear is slacked in damp weather. On the other hand, advantage may be taken of this tendency for tautening lashings, etc., by wetting the rope.

A1.4. Coiling, Uncoiling, and Stowage. *How to Coil and Uncoil Properly.* Right-hand rope should be coiled clockwise. Lay out the rope (perhaps a boat fall) along the deck. Begin coiling it down, close to where it is made fast. Turn the coil over. It is now ready for use. To uncoil, reach down and pull the end of line up through the inside of the coil. The line should uncoil counterclockwise as it pays out.

A1.5. What Not to Do. 1. Don't put strains on kinked lines with buckled strands and don't pull the kink through a block. Coax the strands back into place.

2. Don't drag the line around and get it full of grit and sand.

3. Don't let wear become localized in one spot. Use chafing gear on the line, reverse the line end for end, or cut off the end so that wear is at a different spot.

4. Don't let a weak or damaged spot ruin the whole line. Cut it out and splice the line together again.

5. Don't let the lay of a line become unbalanced by continued use on a winch in the same direction. Reverse the turns periodically, and keep the kinks out.

6. Don't use chain stoppers—use rope stoppers.

7. Don't let the line become fouled in machinery and gears.

8. Don't surge lines on running capstans.

9. Don't put sudden strains on the lines. Surge smoothly.

10. Don't let lines tighten up when wet. Slack off wet lines and halyards.

11. Don't permit rat guards and sharp edges to wear mooring lines. Use chafing gear. Lash well.

12. Don't use the wrong size block for falls. As an approximate rule, blocks

should be three times the circumference and sheaves twice the circumference of the fall.

13. Don't neglect blocks. Inspect and lubricate blocks frequently. Repair or replace them when necessary.

14. Don't lubricate lines. They already are properly lubricated, and over-lubrication can cause loss of strength and difficulty in handling on capstan.

15. Don't throw away worn-out lines. Turn in large, surveyed manila lines for salvage of the sound inner yarns. Use ends and yarns from old lines for lashings and whipping new lines and, finally, turn in all not used for scrap and salvage.

A1.6. Wire Rope. Manufacturers commonly designate the size of wire rope by the diameter and this designation is used in the U.S. Naval specifications. Wire runs from about ¼ to 2¾ inches in diameter.

Manufacture of Wire Rope. The manufacture of wire begins with *billets of steel,* which are 4 by 4 inches in section and about 36 inches long. These are heated for rolling. Upon removal from the furnace the billets pass through the roughing rolls. These rolls reduce the billet to a rod ¾-inch square. During this process the rod is pressed into shapes alternately square and oval, oval and round, etc., thus working the metal thoroughly and improving its qualities. The rods are then passed through the finishing mill rolls for further reduction in size. The rods are then cold drawn through a series of dies to obtain the desired wire gauge diameter. After the final drawing operation, the wire, which is the basic unit for the construction of wire rope, is wound on bobbins for the stranding operation.

From the wire, strands are formed by winding the individual wires in a spiral direction around a core.

The actual formation of wire rope is known as the closing operation and is accomplished in a rope-closing machine. In this machine 6 or 8 strands are usually laid together symmetrically around a hard fiber core, or a wire rope core, to form the finished rope. This arrangement affords the most convenient and compact form, as the strands and the core are practically all of the same size.

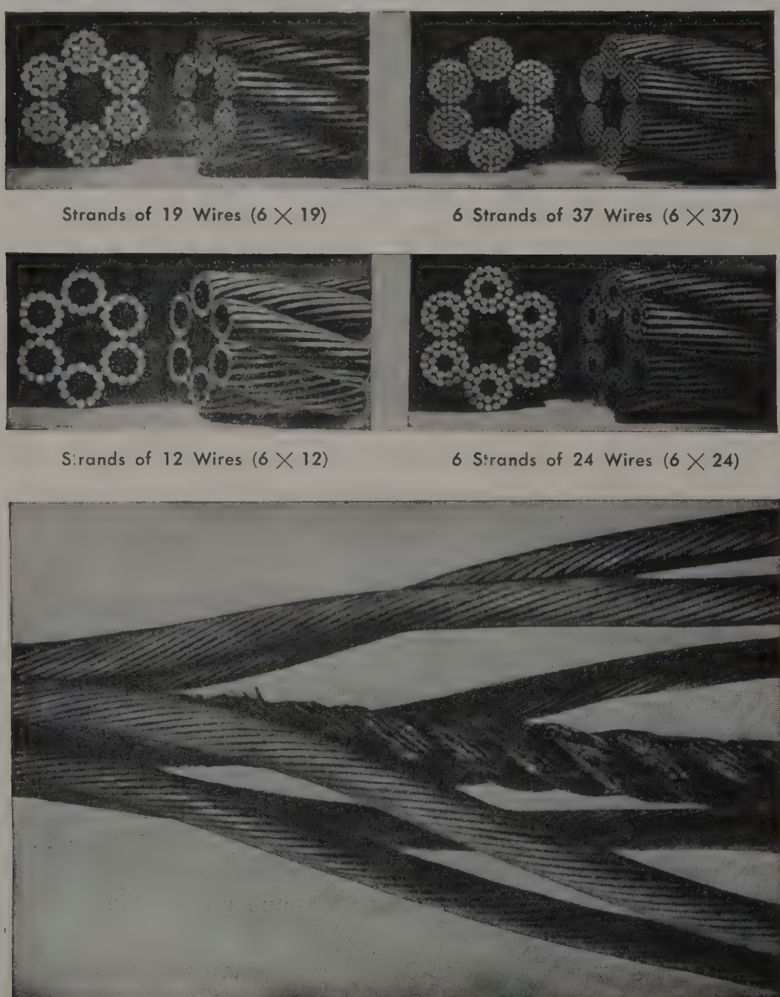
The use of fiber for the center of the rope not only contributes to flexibility, but has the further advantage that the fiber forms a cushion upon which the strands close in as the rope contracts under heavy pull, thus acting with the elasticity of the wire and the "give" which results from the spiral lay, to reduce the effect of sudden stresses. When the fiber center has absorbed its share of the lubricant which should be used upon the rope from time to time, this cushioning will result in a lubrication of the interior wires and greatly reduce the interior friction.

Wire ropes are regularly made in five grades, or strength ranges. These are defined as follows in the order of decreasing strengths; improved plow steel, plow steel, mild plow steel, traction steel, and iron. The weight and the

diameter of a wire rope for a particular purpose can be reduced by using a stronger material; for example, by using high grade plow steel instead of a plow steel rope. Or by the use of a stronger material, the strength (and, therefore, the safe working load) can be increased for a given weight and diameter.

Galvanized-Wire Rope. Galvanized-wire rope should be used if the rope is likely to corrode because of the presence of moisture, as for the standing rigging of a ship. Because the zinc coating is rapidly removed by wear, it should not, in general, be used for hoisting.

Uncoated-Wire Rope. Uncoated-wire rope should be used where it is protected from moisture, as in a building, and for more or less continuous hoisting.



Strands of 19 Wires (6×19)

6 Strands of 37 Wires (6×37)

Strands of 12 Wires (6×12)

6 Strands of 24 Wires (6×24)

Wire Rope Unlaid, Showing Hemp Core

FIG. A1.3 TYPES OF WIRE ROPE

It may be used instead of galvanized-wire rope, where it is exposed to moisture, as for derrick guys, if a protective coating is applied to the rope at regular intervals.

Phosphor-Bronze Wire Rope. Phosphor-bronze wire rope has lower strength than steel-wire rope; therefore the working loads should be lower. The sheaves should also be larger than those for steel rope. It is nonmagnetic and can be used for conditions under which galvanized steel rope does not give satisfaction. Because of these properties it is used on small vessels.

6 by 19 Ungalvanized Steel Wire Rope. This rope is principally used for heavy hoisting and is of very great strength, particularly useful on derricks and dredges. It is the stiffest and strongest construction of the types listed, which is suitable for general hoisting purposes. Sheaves for this type of rope should be larger, if possible, than those used for the other more flexible types, to obtain the best results.

6 by 19 Galvanized Steel Wire Rope. Galvanized rope of this construction may be used for standing rigging, guys, and boat slings. This construction, both ungalvanized and galvanized, is furnished in two grades of steel: "extra strong cast steel" and "high-grade plow steel," of which the latter is the stronger.

6 by 19 Phosphor-Bronze Wire Rope. This rope may be used for lifelines, clearing lines, wheel ropes, or rigging where either noncorrosive or nonmagnetic properties are desired.

Marline-Covered Wire Rope, 5 by 19. Marline-covered wire rope is stronger and more durable than manila rope. The marline covering prevents wearing of the wires and supplies lubricant to them. As the marline wears to a smooth surface, the rope is easily handled or laid in a flat coil. Compared with uncovered wire rope, the marline-covered rope is more easily handled, has greater friction, which is an advantage if it is used on a smooth drum, and is very durable, particularly if it is exposed to gases, grit, or moisture.

Fiber Cores. Cotton may be spun into cores of small diameter more satisfactorily than other fibers. It is therefore required for the cores of small wire ropes. For wire rope of large diameter, hard fibers (manila, sisal, or java, African, Mexican, or Yucatan) are used.

Seizing. The end of a wire rope should be seized to prevent unlaying, which, if it occurs, makes the rope useless. Annealed iron wire should be wound tightly in a close helix around the rope. The seizings may be replaced by fittings if they prevent unlaying of the rope.

DEFINITIONS AND TERMS

(from *Le Tourneau-Westinghouse, Co-Operator*)

The following definitions and terms apply to wire ropes and strands.

Nominal breaking strength—The nominal breaking strength is the value on which designs should be based.

Acceptance breaking strength—The acceptance breaking strength is the minimum value on which compliance with the specification is determined.

Bright wires—Bright wires are wires in ropes or strands that are uncoated.

Core—The core is the foundation member (a twisted fibrous material, a wire strand or an independent wire rope) of a wire rope around which the strands are laid.

Filler wires—Filler wires are small-diameter auxiliary wires for supporting and positioning main wires. Filler wires are sometimes included in the actual wire count and identification of the rope construction.

Galvanized (or coated) wire ropes and strands—Galvanized wire ropes and strands are wire ropes or strands made of zinc coated (galvanized) wires.

Galvanized (zinc coated) wires—In the manufacture of "galvanized" rope wire, the wire is zinc coated at finished size.

Lang lay—In a lang lay wire rope the direction of lay of the wires in the strand and of the strand in the rope is the same. As a result the rope has an appearance that the wires are diagonal to the axis of the rope. The wires and the strands may run to the right—"Right Lang Lay" (commonly called—Lang Lay); or to the left—"Left Lang Lay" (on specific orders only).

Lay—The word "lay" is used by the wire rope industry in two different ways:

(a) The lay is the manner in which the wires in a strand or the strands in a wire rope lay (twisted).

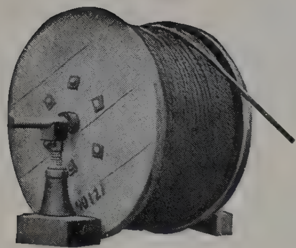
(b) The lay is the distance parallel to the longitudinal axis in which a wire makes a complete turn (spiral or helix) about the axis of the strand or a strand about the axis of the rope. It is also called the lay length or the pitch.

Regular lay—"Regular lay" designates that the wires in the rope strand lay in one direction while the strand itself rotates in the rope in an opposite direction. The rope has therefore an outward appearance that all wires in the rope are roughly parallel to the longitudinal axis of the rope.

Marline clad rope—Marline clad rope is a rope in which the strands are covered by a layer of tarred fibrous material wound to protect the hands, to cushion the strands in the rope and to protect them against wear.

Preformed wire rope—Preformed wire rope is a wire rope in which the strands are permanently shaped to the spiral form they assume in the wire rope.

Care of Wire Rope. Wire rope needs better care than hemp or manila and far better care than it generally receives on shipboard. It should be kept on a reel when not in use. A single kink in the finest wire rope practically ruins it at once. In receiving a line and transferring it from one reel to another, care should be taken to unreel it, instead of slipping off the successive bights over the end of the reel. Fig. A1.4 illustrates the right way and the wrong way of dealing with wire rope under various conditions.



Right Way

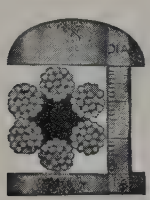
Wrong Way

To Take Rope From Reel

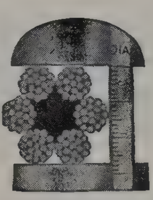
Right Way

Wrong Way

To Take Rope From Coil

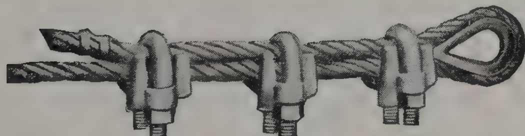


Right Way



Wrong Way

To Measure Diameter



Right Way (U-bolt on Dead End)

Wrong Way (U-bolt on Tension End)

Wire Rope Clips

FIG. A1.4 HANDLING WIRE ROPE

A wire hawser should be gone over thoroughly every month or two with a standard lubricant preservative. It is important that the lubricant, whatever its composition, should be thin enough to penetrate into interstices of the rope and yet that it should have consistency enough to adhere to the wire for a reasonable length of time, after which it should be renewed. Care must be taken to ensure covering the rope all around. A hawser used for towing should be relubricated after use while being reeled up.

Wherever wire rope is to be worked over a sheave, the diameter of the sheave and the speed of running become very important factors. The larger the sheave and the lower the speed, the better. All manufacturers of wire rope prescribe a minimum diameter for sheaves, and their guaranteed breaking strains and estimated safe-working loads are for these minimum diameters and for moderate speed. A high speed increases the wear upon the rope, not only by the friction on the sheaves but still more by the friction of the wires upon each other—a point often overlooked.

The "play" that necessarily goes on between the fibers of a rope being alternately bent and straightened in running over a sheave increases with the speed and is greater with a small sheave than with a large one. The same consideration enters in where a rope is alternately stretched and relaxed under a straight but varying pull, as, for example, in towing.

The diameter of the sheave over which the rope is worked should never be less than 20 times that of the rope itself; and the less flexible the rope, the larger should be the sheave.

It is important that the score of the sheave should be of such size as to carry the rope without excessive play and, above all, without friction against the sides of the score. Metal sheaves are not required to be lined with wood or leather.

The turns of the rope should never be allowed to overlap on the drum of the winch.

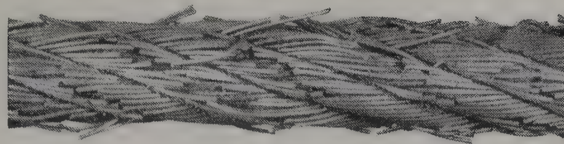
As the wear of the rope over a sheave increases more rapidly with the speed than with the load, it is better, when an increased output is demanded, to increase the load rather than the speed.

In addition to the question of friction in running over a sheave, the distortion of the rope wherever it passes around a relatively sharp bend, whether on a moving sheave or a stationary chock or bollard, is a factor of great importance. Fibers farthest from the center of the curve are stretched, while those which hug the round of the bend are compressed. Thus the outer fibers give way before the inner ones begin to feel the strain.

By far the most unfavorable conditions to which wire rope can be subjected are those wherein it runs over sheaves that give it a reverse bend like the letter S; hence it passes over one sheave with a bend to the right and immediately afterwards swings around another with a bend to the left.

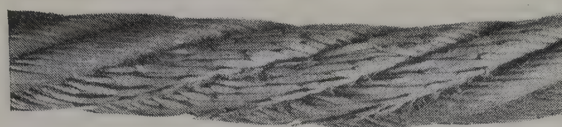
Wire rope should be condemned when the outside wires are worn down to one half their original diameter, or when it is apparent from broken wires or

1. SHEAVES TOO SMALL. This rope was forced to travel continuously over sheaves whose diameters were too small. This caused severe bending fatigue. Result — broken wires, ruined rope.



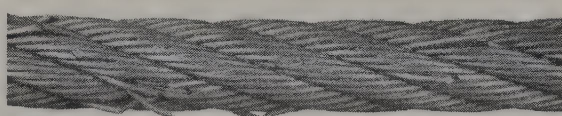
2. DRUM ABRASION and abuse caused this. The rope was scuffed over and over against previous wraps on a flat-faced drum. Its life ended long before it should have.

3. KINKING CAUSED THIS. This dog-leg, or kink, was finally straightened out of this rope — but notice the uneven wear at the point where the kink had been. Beware of dog-legs! They're expensive.



4. UNEVEN DRUM WINDING is a frequent rope-wrecker. This rope was wound unevenly time after time on to a drum. Result — it is crushed and flattened. The service cost of this rope was unnecessarily high. WATCH how the rope winds!

5. ACIDS DID THIS. This rope was attacked by high sulphur content in the water and crude oil through which the rope operated. A heavily internally lubricated rope will resist the action for a time.



6. FOUL PLAY "killed" this rope. While in operation, this rope met with an accident that mashed and cut many of its wires. Result — a ruined rope, and many a rope dollar wasted that could have been saved.

FIG. A1.5 INSPECTION OF WIRE ROPE. DON'T WAIT UNTIL A FAILURE OCCURS BEFORE EXAMINING YOUR WIRE ROPE. LOOK IT OVER AT REGULAR INTERVALS. *Courtesy* Le Tourneau-Westinghouse Co-Operator

other abnormal indications that it has been subjected to danger by excessive strains, or to a sharp bend resulting in a pronounced kink.

A1.7. Guide to Using Nylon: *Maintenance.*

1. Nylon rope will hold a load even though a considerable number of the yarns are abraded. Ordinarily, when abrasion is localized, the rope may be made satisfactory for reuse by cutting away the chafed section and splicing the ends. Chafing and stretching do not necessarily indicate the load-carrying ability of nylon rope.

2. Splice nylon rope as you would manila rope except that tape instead of seizing stuff should be used for whipping the strands and rope. Also nylon rope,

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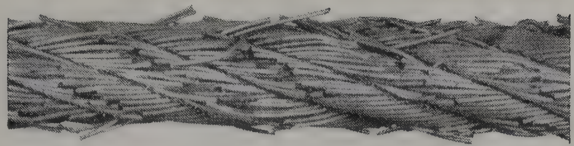

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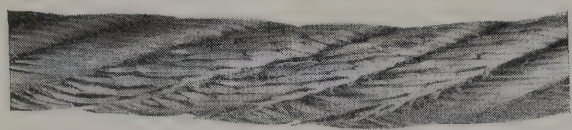

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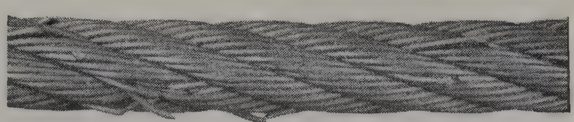

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2. Splice nylon rope as you would manila rope except that tape instead of seizing stuff should be used for whipping the strands and rope. Also nylon rope,

because of its smoothness and elasticity, requires at least one more tuck. For heavy load applications such as towing, take an additional backtuck with each strand.

3. Should nylon rope become iced over, thaw it carefully at moderate temperature and drain before stowing.

4. Should nylon rope become slippery because of the accumulation of oil or grease, scrub it down.

5. *General Use:* Do not uncoil new nylon rope by pulling the end up through the eye of the coil. Unreel it as you would wire rope.

6. New cable-laid nylon hawsers tend to be stiff and difficult to handle. To alleviate this condition, tension the cables for 20 minutes at 30 percent extension (100 feet when tensioned would measure 130 feet).

7. When the stretch of nylon becomes excessive, double up the lines by passing the bight, thereby halving the elongation under load. This reduces the hazard of snapback, since the rope will usually part near the eye. For drydocking and other close control work, stretch can be reduced to one half by doubling the lines.

8. When new cable-laid nylon hawsers are strained, sharp cracking noises will be heard. The noises are associated with readjustment of the rope strands in the stretched cable. Under normal safe-working loads, the rope will stretch one third of its length.

9. Wet nylon hawsers under strain emit steamlike water vapor. This phenomenon is normal under safe-working loads.

10. Nylon rope can withstand repeated stretching with no serious effect. When under load it thins out; but when free of tension, it returns to its normal size. The critical point of loading is 40 percent extension, i.e., a 10-foot length would stretch to 14 feet when under load. Should the stretch exceed 40 percent, the rope is in danger of parting.

11. When sets of ropes are to be used in parallel, as are boatfalls, do not pair nylon rope with low elongation rope, such as wire or manila.

12. Use nylon rope stopper for holding nylon hawsers under load. Do not use manila or chain.

13. When handling nylon rope without a powered reel, avoid coiling it in the same direction all the time, since this will tend to unbalance the lay.

14. Bitts, chocks, and other holding devices used with nylon rope should have smooth surfaces to reduce abrasion and minimize surging of nylon ropes under working conditions. Use chafing gear where there are sharp metal edges. During reeling or heaving-in operations, take care that thimbles and connecting links do not chafe or cut the nylon hawsers.

15. Since, normally, plain-laid nylon rope is right-laid, coil it on bitts, capstans, or reels in a clockwise direction.

16. Do not use wire or spring lay rope on the same chock or bitt with nylon rope.

17. Plain-laid nylon hawsers tend to elongate around bitts when loaded. To minimize excessive lengthening, take a turn under the horn and cross the line on itself before taking more turns.

18. When nylon hawsers are used on capstans for heavy towing or impact loading, take six turns on the capstan, two turns overlaying the last four turns. This procedure reduces the hazard of sudden surges on rendering out.

19. For mooring purposes with low freeboard vessels where the tide differential is average, make up at half tide. No further handling should be required.

20. Nylon rope under heavy strain may develop glazed areas where it has worked against bitt and chock surfaces. This condition may be caused by the removal of paint from metal surfaces or the fusing of nylon fibers. In either case, the effect on the rope strength is negligible.

Alongside Towing:

21. Make up forward and backing tow lines as close as possible without regard to sharp bends.

22. Take up slack in relaxed line while the other line is under heavy load.

23. When easing pull, the tug may have to reverse engines slightly to counteract the elastic property of nylon and thus avoid "snapback" action.

Precautions:

24. Nylon rope on parting is stretched 50 percent. The stretch is recovered instantaneously with resulting snapback. In view of this, it is imperative that no one stand in direct line of pull when heavy loads are applied.

25. Do not use a single part of plain-laid rope for hauling or hoisting any load that is free to rotate. If one part of rope is essential, use cable-laid nylon hawsers.

26. Do not stow nylon rope in strong sunlight for long periods. Cover it with tarpaulins. During stowage, keep it away from heat and strong chemicals.

27. Be extremely careful when easing out nylon rope around bitts and cleats under heavy load. Because its coefficient of friction is lower than that of manila, the nylon rope may slip when eased out and cause injury to personnel unfamiliar with its oddities.

28. For control in easing out, take two or three round turns on the bitt before figure-eighting the line. Use of the round turns provides a means for closer control in easing out or surging. Always stand well clear of the bitts during these operations.

Life Expectancy: Nylon rope properly handled and maintained should remain serviceable more than five times longer than manila rope subjected to the same use. Adherence to the foregoing instructions combined with the usual safe practices followed for manila rope will give all the advantages of nylon rope plus savings in cordage allowances.

Harmful Chemicals: The chemicals listed here have a permanent effect on nylon yarn. Action takes place at various temperatures and concentrations according to the chemical involved.

Concentrated formic acid
Benzyl alcohol (at a boil)
Phenol
Cresols
Xylenols
Chlorinated phenols
Concentrated nitric acid
Concentrated sulfuric acid
Calcium chloride (in methanol)
Calcium chloride (in glacial acetic acid; ethylene chlorohydrin; ethylene glycol)
Zinc chloride in methanol
Concentrated hydrochloric acid

TABLE A1.1. PHYSICAL REQUIREMENTS FOR FIBER ROPE, THREE STRAND

Size (Circumference) Nominal	Diameter (Approximate Nominal)	Length of Coil (Minimum)	Gross Wt. of Coil (Approx.)	Length per Pound (Minimum)	Breaking Strength (Minimum)	
					Manila	Sisal
Inches	*Inches*	*Feet*	*Pounds*	*Feet*	*Pounds*	*Pounds*
5/8	3/16 (6 yarns)	3,335	50	66.6	450	360
3/4	1/4 (6 yarns)	2,500	50	50.0	600	480
1	5/16 (9 yarns)	1,725	50	34.5	1,000	800
1 1/8	3/8 (12 yarns)	1,220	50	24.4	1,350	1,080
1 1/4	7/16 (15 yarns)	1,200	63	19.0	1,750	1,400
1 1/2	1/2 (21 yarns)	1,200	90	13.3	2,650	2,120
1 3/4	9/16	1,200	125	9.61	3,450	2,760
2	5/8	1,200	160	7.50	4,400	3,520
2 1/4	3/4	1,200	200	6.00	5,400	4,320
2 1/2	13/16	1,200	234	5.13	6,500	5,200
2 3/4	7/8	1,200	270	4.45	7,700	6,160
3	1	1,200	324	3.71	9,000	7,200
3 1/4	1 1/16	1,200	375	3.20	10,500	8,400
3 1/2	1 1/8	1,200	432	2.78	12,000	9,600
3 3/4	1 1/4	1,200	502	2.40	13,500	10,800
4	1 5/16	1,200	576	2.09	15,000	12,000
4 1/2	1 1/2	1,200	720	1.67	18,500	14,800
5	1 5/8	1,200	893	1.34	22,500	18,000
5 1/2	1 3/4	1,200	1,073	1.12	26,500	21,200
6	2	1,200	1,290	.930	31,000	24,800
7	2 1/4	1,200	1,752	.685	41,000	32,800
8	2 5/8	1,200	2,290	.524	52,000	41,600
9	3	1,200	2,900	.414	64,000	51,200
10	3 1/4	1,200	3,590	.335	77,000	61,600
11	3 5/8	1,200	4,400	.273	91,000	72,800
12	4	1,200	5,225	.230	105,000	84,000

TABLE A1.2. LENGTH AND WEIGHT FOR ROPE 4 INCHES AND LARGER (U.S. NAVY REQUIREMENTS)

Nominal Size (Circumference)	Minimum Length of Coil	Approximate Coil Weight (Gross)
Inches	*Feet*	*Pounds*
4	900	432
4½	900	540
5	900	670
5½	900	805
6	600	645
7	600	875
8	600	1,145
9	600	1,450
10	600	1,795
11	600	2,200
12	600	2,610

TABLE A1.3. LENGTH AND WEIGHT FOR ROPE (U.S. COAST GUARD REQUIREMENTS)

Nominal Size (Circumference)	Minimum Length of Coil	Approximate Coil Weight (Gross)
Inches	*Feet*	*Pounds*
¾	2,750	55
1	2,250	65
1⅛	1,620	66
1½	2,700	203
6	900	972
8	900	1,719
10	1,200	3,588
12	1,500	6,540

TABLE A1.4. SPECIFICATION COMPARISON FOR FIBER ROPE

	Size		Manila		Nylon		Dacron		Polypropylene	
Threads	Diam.	Cir.	Lbs. 100 ft.	Tensile Strength	Lbs. 100 ft.	Tensile Strength	Lbs. 100 ft.	Tensile Strength	Lbs. 100 ft.	Tensile Strength
6	1/16	5/8	1.5	450	.9	1,050	1.3	1,200	0.7	800
6	1/4	3/4	2.0	600	1.5	1,800	2.0	2,000	1.2	1,200
9	5/16	1	2.9	1,000	2.5	2,750	3.2	3,150	1.85	1,900
12	3/8	1 1/8	4.1	1,350	3.6	4,000	4.5	4,350	2.8	2,700
15	7/16	1 1/4	5.3	1,750	5.0	5,500	5.9	5,650	3.8	3,400
21	1/2	1 1/2	7.5	2,650	6.6	7,300	7.9	7,550	4.7	4,100
27	9/16	1 3/4	10.4	3,450	8.2	9,075	9.6	9,000	6.0	4,700
	5/8	2	13.3	4,400	10.0	10,900	13.0	11,600	7.5	5,900
	3/4	2 1/4	16.7	5,400	14.5	15,600	17.7	16,000	10.7	8,100
	13/16	2 1/2	19.5	6,500	16.8	17,700	21.9	19,800	12.9	9,800
	7/8	2 3/4	22.5	7,700	20.0	21,400	25.2	22,500	15.4	11,600
	1	3	27.0	9,000	25.8	27,000	30.0	26,400	18.3	13,900
	1 1/16	3 1/4	31.3	10,500	28.5	30,500	34.8	30,500	20.4	15,300
	1 1/8	3 1/2	36.0	12,000	32.0	33,500	40.3	34,600	23.7	18,000
	1 1/4	3 3/4	41.8	13,500	39.5	41,300	46.3	39,300	27.2	20,500
	1 5/16	4	48.0	15,000	46.0	46,500	52.5	44,000	30.8	23,500
	1 1/2	4 1/2	60.0	18,500	56.5	56,500	66.5	55,000	38.1	29,000
	1 5/8	5	74.4	22,500	70	70,000	82.0	67,500	47.5	36,000
	1 3/4	5 1/2	89.5	26,500	83	82,800	98.5	80,000	58.0	43,500
	2	6	108	31,000	98	98,000	116	93,500	68.0	52,000
	2 1/8	6 1/2	125	36,000	112	112,500	135	108,000	80.0	61,000
	2 1/4	7	146	41,000	131	131,000	157	124,000	92.6	70,000
	2 1/2	7 1/2	167	46,500	150	149,000	178	141,000	107	80,000
	2 5/8	8	191	52,000	170	170,000	203	160,000	121	90,000
	2 7/8	8 1/2	215	58,000	190	190,000	227	177,000	137	102,000
	3	9	242	64,000	213	212,000	253	193,000	153	114,000
	3 1/8	9 1/2	269	71,000	233	232,000				
	3 1/4	10	299	77,000	248	245,000	300	243,000	190	138,000
	3 1/2	11	367	91,000	303	305,000	360	273,000	230	165,000
	3 3/4	12	436	105,000	357	355,000	425	330,000	274	192,000

TABLE A1.5. PHYSICAL PROPERTIES, NYLON ROPE

Circumference at Load P	Tolerance Plus or Minus	Approx. Diameter	Load P (200 × D²)	Feet per Pound at Load P Minimum	Hardness Minimum	Hardness Maximum	Breaking Strength Minimum
Inches	Inch	Inches	Pounds	Feet	Lbs.	Lbs.	Pounds
5/8	1/16	3/16	7	100.0	5	25	1,000
3/4	1/16	1/4	12	66.0	5	25	1,500
1	1/16	5/16	20	36.0	5	25	2,500
1 1/8	1/16	3/8	28	28.5	5	25	3,000
1 1/4	1/16	7/16	38	20.0	5	25	4,500
1 1/2	1/16	1/2	50	16.5	5	25	5,500
1 3/4	1/16	9/16	65	12.5	5	25	7,000
2	1/16	5/8	80	9.7	5	25	8,400
2 1/4	1/16	3/4	110	7.2	5	25	11,500
2 1/2	1/16	13/16	130	6.2	5	25	14,000
2 3/4	1/16	15/16	175	5.0	5	25	16,000
3	1/8	1	200	4.1	20	100	22,000
3 1/2	1/8	1 1/8	250	3.0	20	100	28,500
3 3/4	1/8	1 1/4	310	2.6	20	100	33,000
4	1/8	1 5/16	345	2.3	20	100	27,500
4 1/2	1/8	1 1/2	450	1.8	20	100	46,000
5	1/8	1 5/8	530	1.5	20	100	57,000
5 1/2	1/8	1 3/4	610	1.25	20	100	68,000
6	1/8	2	800	1.00	20	100	81,000
6 1/2	1/8	2 1/8	900	0.90	20	100	90,000
7	1/4	2 1/4	1,000	.71	20	100	110,000
8	1/4	2 5/8	1,400	.55	20	100	137,000
9	1/4	3	1,800	.43	20	100	170,000
10	1/4	3 1/4	2,100	.34	20	100	200,000
11	1/4	3 3/8	2,600	.285	20	100	240,000
12	1/4	4	3,200	.24	20	100	280,000

TABLE A1.6. SIZE OF WIRE ROPES TO REPLACE MANILA LINES

Manila Rope		6 x 12 Wire Rope Type III, Class 2		6 x 24 Wire Rope Type III, Class 3		6 x 37 Wire Rope Type I, Class 3	
Circumference (Inches)	Strength (Pounds)	Diameter (Inches)	Strength (Pounds)	Diameter (Inches)	Strength (Pounds)	Diameter (Inches)	Strength (Pounds)
4	15,000	5/8	18,320	1/2	16,800	1/2	20,400
5	22,500	3/4	26,200	5/8	26,000	9/16	25,800
6	31,000	7/8	35,400	3/4	37,200	5/8	31,600
7	41,000	1	46,000	7/8	50,600	3/4	45,200
8	52,000	1 1/8	58,000	1	65,600	7/8	61,200
9	64,000	1 1/4	71,200	1 1/16	73,800	1	79,600
10	77,000	1 3/8	85,600	1 1/8	82,400	1	79,600
11	91,000	1 1/2	101,400	1 1/4	101,400	1 1/8	100,200
12	105,000	1 5/8	118,400	1 3/8	122,000	1 1/4	123,000

APPENDIX

2

Knotting and Splicing

A2.1. Working in Fiber Rope—Knots (Fig. A2.1). This plate shows a number of simple knots, all of which are made with the end of a single rope. (The word *line* is properly used in the Navy instead of *rope.*)

Overhand Knot. A. A simple knot formed by passing the end of a rope over the standing part and through the bight.

Bowline. B. One of the most common and useful knots. It forms an eye which may be of any length and which cannot slip. It is used for lowering men over the side, to form an eye in the end of a hawser to be thrown over a bollard in handling a ship alongside of a dock, and for a great variety of similar purposes. Place the end part on the standing part and form a loop with the end through; pass end under standing part; bring it back through the loop.

Running Bowline. C. A convenient form of running an eye. Formed by making a bowline over its own standing part.

Bowline on a Bight. D and E. The bowline made with bight of a line. Dip the open single bight (b) over both double bights (a) and up above the loop and haul taut. Used where a greater strength than given by a single bowline is necessary, or when the end of the rope is not accessible.

Cat's Paw. F. A double loop formed by twisting two bights of a rope. The hook of a tackle is passed through them. Convenient and secure.

Sheep Shank. G. Used to shorten a rope. Lay the bight of the rope in three parts, and half hitch each part around the bight of the other two parts.

Figure Eight. H. A knot resembling the figure eight and used to prevent the end of the rope from unreeving when rove through blocks. Pass the end of the rope around the bight over its own part and through the loop.

Blackwall Hitch. I and J. A hitch either single or double around the back of a hook, the end on one side of the hook and the standing part on top, on the other side of the hook.

French Bowline (Fig. A2.2). When sending a man over the side on hazardous work, into a smoke-filled hold, or anywhere where he may have to use both hands, make use of the French bowline. The bowline is formed in the same fashion as the regular bowline, except that the end (D), instead of going about the standard part (E) at once, is given a round turn about the loop of the eye (A), and then the knot is finished off as before. This leaves two eyes that

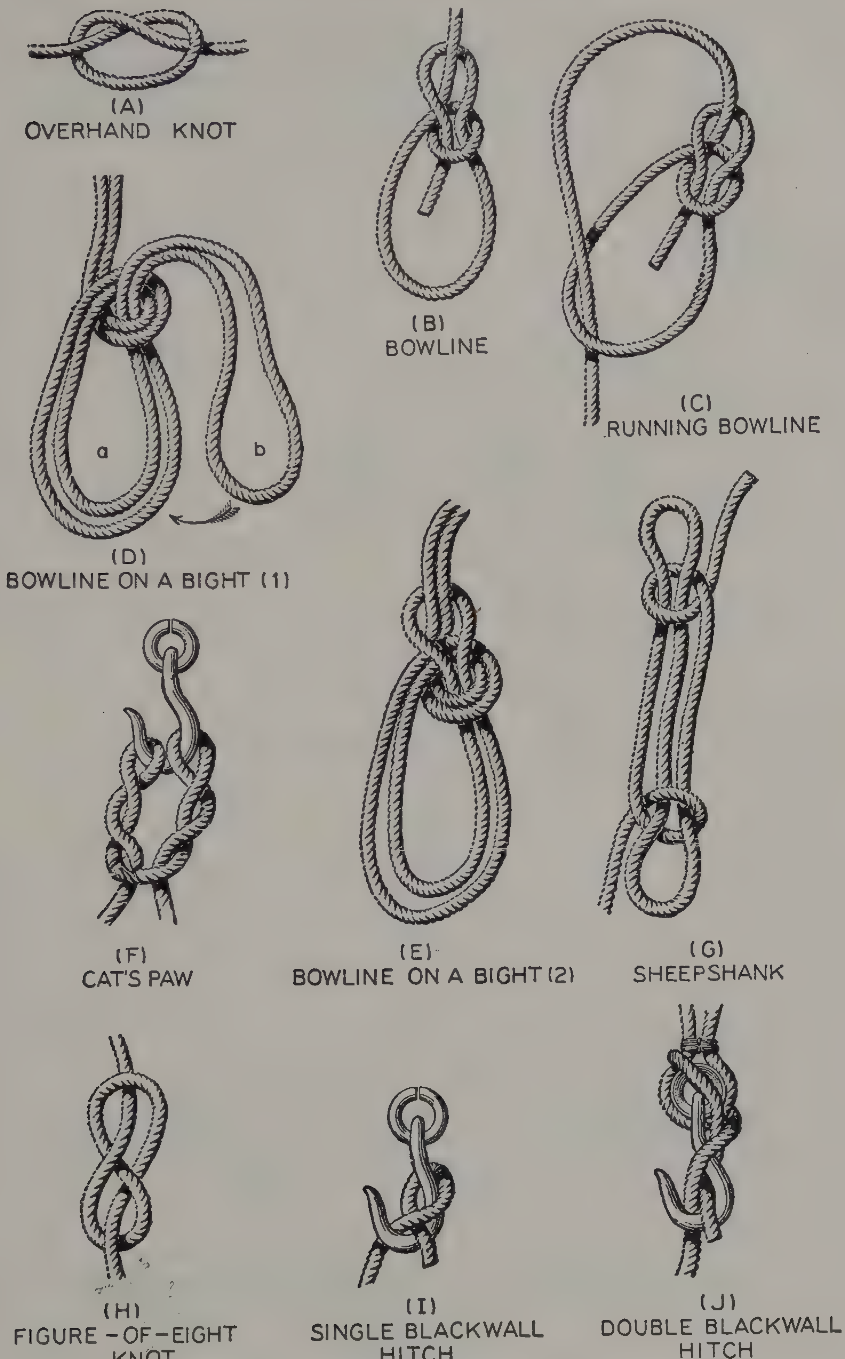


FIG. A2.1 KNOTS AND HITCHES (SHOWN LOOSE, NOT HAULED TAUT)

are loosely connected through the loop neck. The eyes are made so that a man can sit in one—(b)—while the other—(c)—goes under his armpits, the knot being at his breast. The weight of the man hauls the armpit eye taut, he is safe against falling out and is held upright if unconscious. Never use manila if there is a chance of it catching fire.

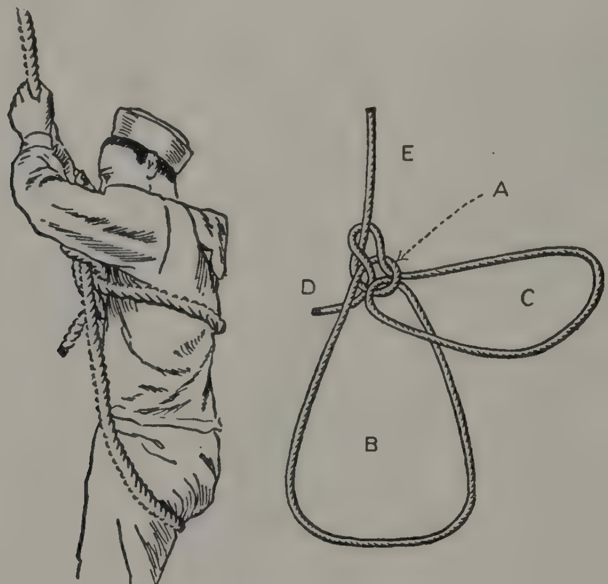


FIG. A2.2

A2.2. Bends (Fig. A2.3). This plate shows a series of knots for joining the ends of the two ropes or the two ends of the same rope. This is perhaps the most important group of knots with which we have to deal.

Square or Reef Knot. A. A most important knot and used for a great variety of purposes. Formed from an overhand knot by crossing the ends and bringing one end up through the bight alongside its own part.

Granny Knot. B. Frequently confused with the square knot. Unseamanlike knot made, instead of a square knot, by a green hand.

Sheet or Becket Bend, single. C. Used in bending on flags not fitted with snap hooks and very efficient for the purpose of uniting two ends of a rope or a rope's end to an eye. Made by passing the end of a rope up through the bight (eye) of another, around both parts and under its own part.

Sheet Bend, double. D. Here the end of the bending line is passed twice around the standing line and through its own part, giving added security.

Single Carrick Bend. E and F. A knot made by first crossing the end of one rope and then passing the end of the other down through the bight, under the standing part, over the end and down through the bight again (rarely used).

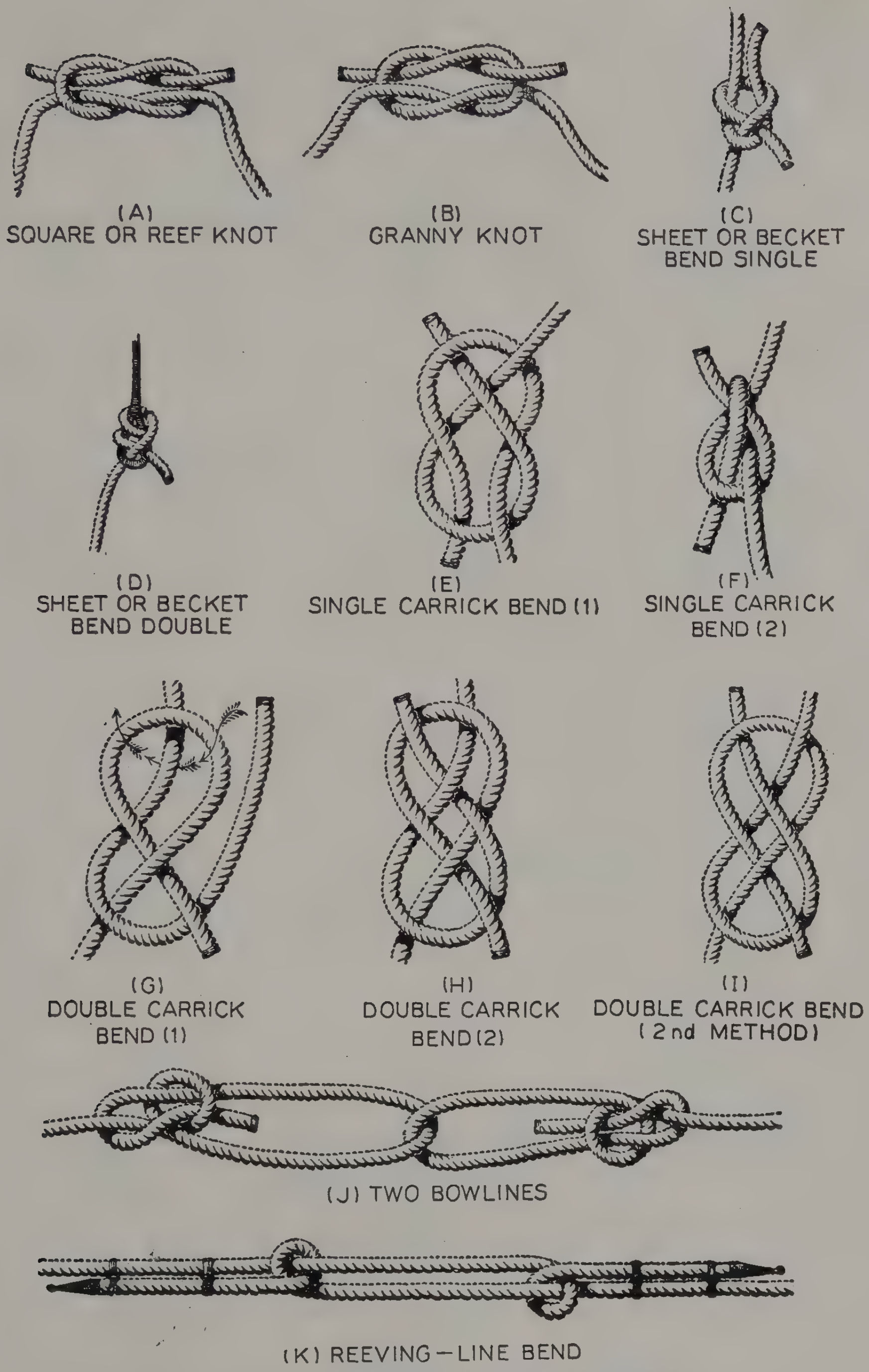


FIG. A2.3 BENDING TWO ROPES TOGETHER

Double Carrick Bend. G, H, and I. More secure than the single Carrick (both ends coming out on different sides). With both, it is well to seize the ends to their own parts. Excellent for bending two hawsers together.

Two Bowlines. J. Convenient way of bending two hawsers together. Is somewhat bulky for use where the lines are to be veered out through a chock, and tends to part where hawsers meet.

Reeving-Line Bend. K. A method of connecting two hawsers in such a way that they will reeve through an opening, offering as little obstruction as possible. Made by taking a half hitch with each end around the other hawser and seizing the ends.

A.2.3. Bends (Fig. A2.4). This plate shows various ways of securing lines to spars, posts, rings, etc.

Studding Sail Tack Bend. A. A useful bend for a variety of purposes where it is important to have no danger of coming adrift through the flapping of sail and lines.

Studding Sail Halyard Bend. B. The greater the pull on the halyards, the more tightly the parts of the bend are jammed against the spar. Formed by taking a round turn with the end coming around the standing part, under both turns and tucked over and under the turns.

Fisherman's Bend. C. Used for securing a rope to a buoy, or a hawser to the ring or jew's-harp of an anchor. Formed by passing the end twice round the ring and under the turns. Seize the end back.

Timber Hitch. D. Useful when towing spars. Formed by passing the end around the spar and its own standing part; then pass several turns around its own part.

Timber Hitch and Half Hitch. E. The half hitch is taken first and the timber hitch afterwards formed with the end.

Rolling Hitch. F and H. Very useful where a rope is to be bent to a spar or to the standing part (not the end) of another rope, or to a chain (as in clearing hawse). Pass the end twice round the spar or rope, crossing the standing part on the top side each time; then hitch the end round the spar or rope, on the opposite side of the two turns.

Round Turn and Two Half Hitches. G. For making a hawser fast to a bollard, spar, or another rope. Most useful and popular way to make a line fast.

Two Half Hitches. I. Another method of bending a rope's end to a spar, stanchion, bollard, or ring. Formed by leading the end over and under and up through the standing part and repeating the process.

Clove Hitch. J. One of the most common hitches. Pass the end around the spar, crossing the standing part, then around the spar again, bringing the end through between the end part and standing part under its own part.

Knotting a Rope Yarn (Fig. A2.5A). Used in making a strap where rope yarn is used. The parts shown in the drawing are hauled taut. The rope yarn will then be secured without give.

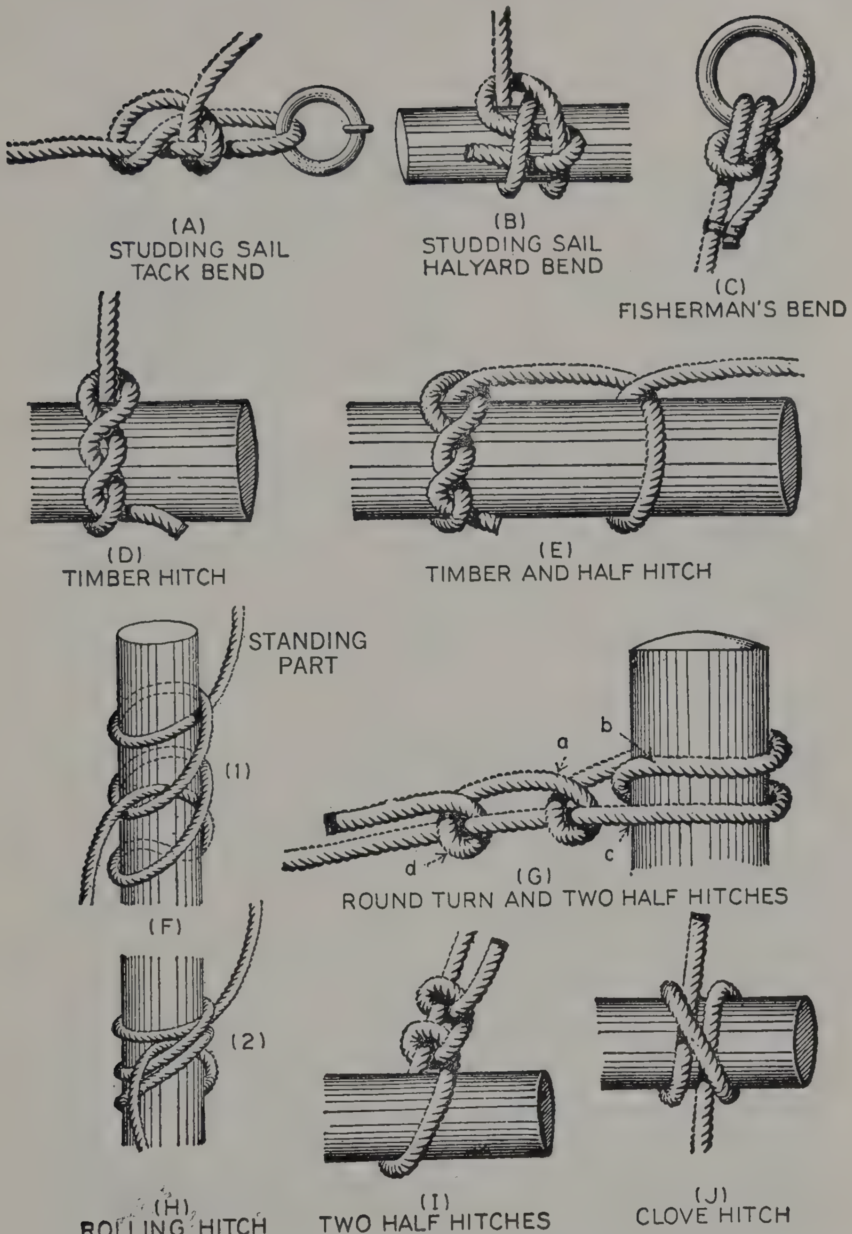


FIG. A2.4 BENDING A LINE

Stopper on a Rope (Fig. A2.5B). A short length of rope secured at one end, and used in securing or checking a running rope, e.g., deck stopper, boat fall stopper, etc.

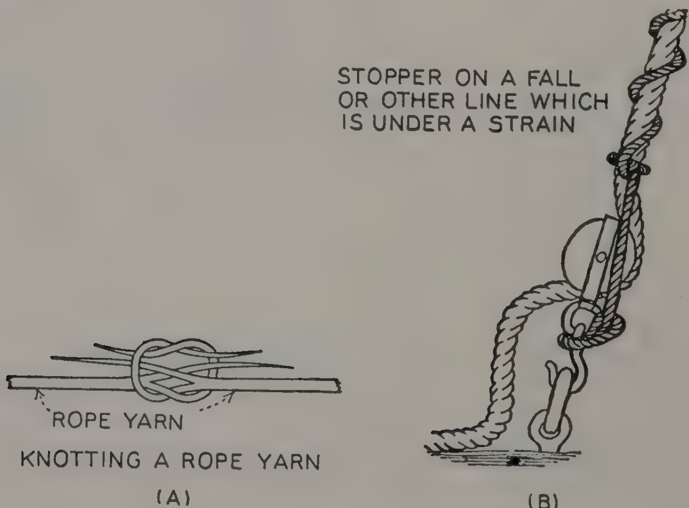


FIG. A2.5

A2.4. Passing a Strap. The loop-like single strap (or selvagee) is used to attach a block to a part of the rigging or to a spar. It is twisted around the rigging and the block is hooked into the bight as follows:

First Method (Fig. A2.6, top). A. Take the loop of one end of strap and hold same on hawser; now pass other end of strap close around hawser until it is expended, allowing sufficient length to bring the two ends together.

Second Method (Fig. A2.6, top). B. Take strap and hold center against hawser and pass both (crossing same) ends around hawser in opposite directions. Bring ends together and hook block.

Third Method (Fig. A2.6, top). C. Spread loop of one end of strap at right angles to hawser, now pass other end of strap around hawser inside of loop until strap is expended. Bring ends together to hook block.

Signal Halyard Splice (Fig. A2.6, bottom). A signal halyard splice is an eye turned in the end of signal halyard for snap hooks and rings.

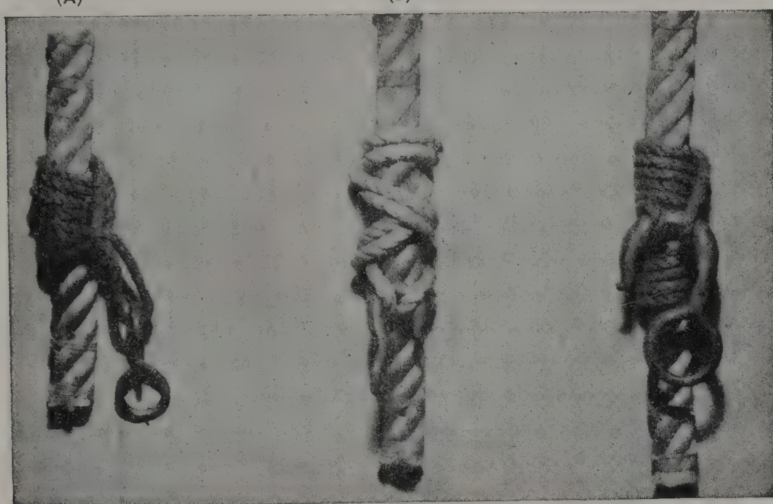
1. About 1 inch or 1½ inches from end of halyard cut out three strands. Insert sail needle and twine through halyard about 1½ inches from end and make hitch; make another hitch with needle and twine near end of halyard (this tapers end of halyard for tucking).
2. Six inches from end of halyard insert a pricker down through center of halyard for about two inches.
3. Haul sail needle, twine, and tapered end through halyard ring or snap hook to be used. Withdraw pricker and insert sail needle, twine, and

tapered end through center of halyard. Cut off tapered end, leaving about one-half inch of end.

4. Haul out and smooth splice.

Note: For preservation, splice and fittings may be dipped in a solution of boiling beeswax.

(A) (B) (C)



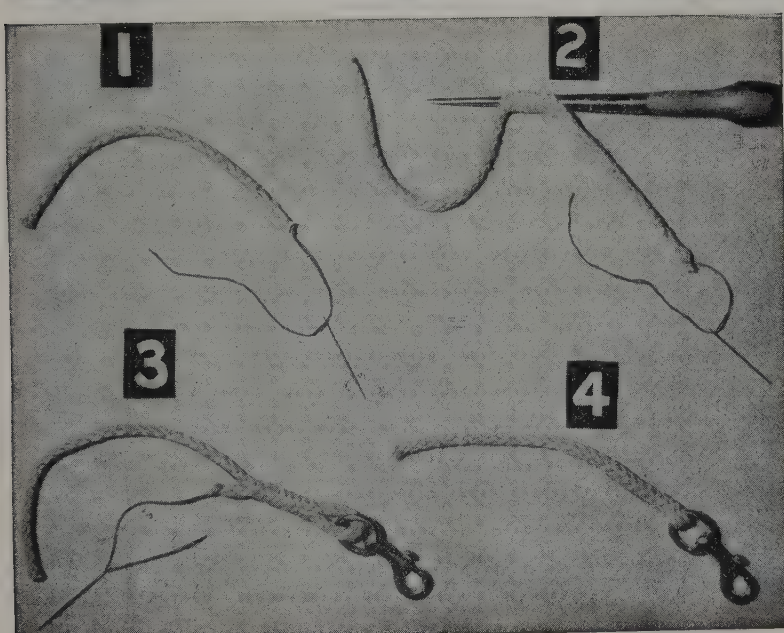


FIG. A2.6 *(Top)* THREE METHODS OF PASSING A STRAP
(Bottom) SIGNAL HALYARD SPLICE

WHIPPING THE END OF A ROPE

FIG. A2.7 KNOTS WORKED IN THE END OF A ROPE

A2.5. Knots Worked in the End of a Rope (Fig. A2.7). This plate shows a series of knots which are worked in the end or the body of the rope by unlaying the rope and using its own strands. A whipping is usually put on below the point where the knot is to be. Knots of this kind are sometimes used to give a finish to the end of the rope, sometimes to prevent unreeving, and sometimes merely for ornamental purposes.

Wall Knot. A. Unlay the strands sufficiently to form the knot. Form a bight with strand 1 and pass strand 2 around the end of it, also strand 3 around the end of 2 and through the bight of 1, hauling the ends taut.

Wall and Crown. B. Lay strand 1 over the center of the wall, strand 2 over 1, and strand 3 over 2 and under 1. Haul the strands taut and form the knot.

Double Wall and Single Crown. C.

Double Wall and Double Crown or "Man-Rope Knot." D. The ends come out underneath and are hidden. Used at the end of a man-rope.

Matthew Walker Knot, Double and Single. E, F, G, and H.

Laniard Knot. I.

Whipping the End of a Rope. J, K, and L. To prevent unlaying or fraying out. Lay the end of a length of stout twine along the rope and pass a number of turns around the rope and over the end of the whipping, hauling each turn taut. J. Then lay the other end of the whipping along the rope in the direction from the first end, and pass a number of turns, on the bight, over this end. K. Haul the end through and trim off.

Sailmaker's Whipping. Put on with a needle and twine. The rope is first struck through between two strands with the needle and the twine is drawn to the end. Several turns are passed around the rope and the rope struck through at each end of the whipping between the strands. Crossing turns are passed between strands and secured with two half hitches and hauled close down.

A2.6. Splicing (Fig. A2.8). There are various forms of splices for joining the ends of two ropes permanently, or for bending the end of a rope upon itself to form a permanent eye. In making these, when the strands of a rope are to be tucked, the lay of the rope where they go through is opened out by means of a fid, and the strand tucked through once in its full size, then reduced in size by cutting away a certain number of threads, tucked a second time, reduced once more in size, and tucked again. It is thus tucked once full size, once two-thirds, and once one-third size. This produces a tapered and much neater splice than if it were tucked three times in full size.

Length of Splices. For eye splices and short splices whether in manila or wire, from 12 to 24 inches should be allowed for forming the splice; for long splices, ten times the circumference of the rope.

A Three-Strand Eye Splice. B, C, and D. After the rope is unlaid some of the strands are brought back upon the body of the rope at a point which will form an eye of the size that is wanted.

Middle strand (a) up and a strand laying on either side have eye toward you. Tuck as follows: (B). Middle strand (a) under strand below it, left hand

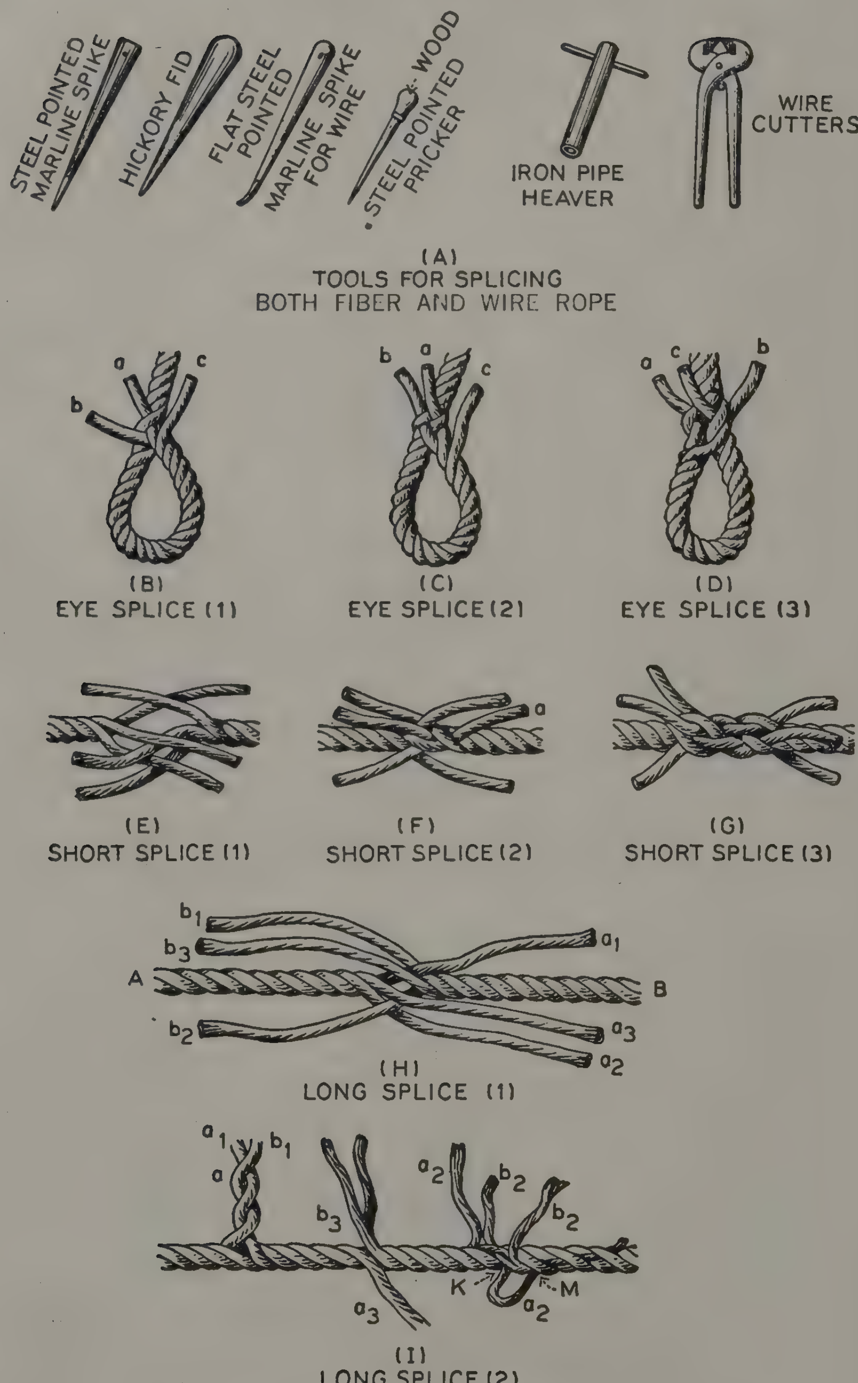


FIG. A2.8 SPLICES, FIBER ROPE

strand (b) over the strand under which the first strand was tucked and under the next (C). Now turn the splice over (D). Give the last strand (c) an extra twist with the lay and tuck it under the remaining strand. All strands are tucked from right to left. After first full tuck with the three strands, tuck each over and under twice more. If splice is to be finished and served, cut out a third of the yarns of the strand as mentioned earlier.

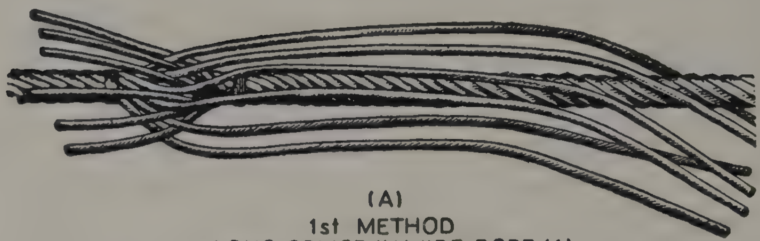
A Four-Strand Eye Splice. Here the first strand (left strand) is tucked under two (but this is for the first tuck only); remaining strands each under one. All tucks from right to left.

A Short Splice. E, F, and G. Two ropes are unlaid for a short distance and married together with strands interlacing (E). The strands of each rope are then tucked through the lay of the other rope exactly as has been described in the case of an eye splice.

A Long Splice. H and I. Here the ropes are unlaid for a greater distance than for a short splice and the ends brought together as before, with strands interlacing. Instead now of tucking at once, we proceed as follows: Unlay a_1, one of the strands of A, for a considerable distance, and in place of it lay up b_1, the adjoining strand of B, thus working a strand of B into A, for, say, a foot and a half to two feet. For convenience now twist up a_1 and b_1 together temporarily, as in I. Turn the rope end for end, unlay b_2, one of the strands of B, and in place of it lay up a_2, the adjoining strand of A. a_3 and b_3 are left lying beside each other without being unlaid. We now have three pairs of strands at different points of the rope. Beginning with a_2 and b_2 (for example) separate each of the strands into two parts, and taking one half of each strand, overhand knot these together (K, I) and tuck them as in a short splice, over one and under one of the full remaining strands in the rope (M, I). The other pairs of strands (a_1, b_1) (a_2, b_2) are similarly reduced, knotted, and tucked. The spare half of each strand is trimmed off smooth, as are the ends of the other halves after they have been tucked.

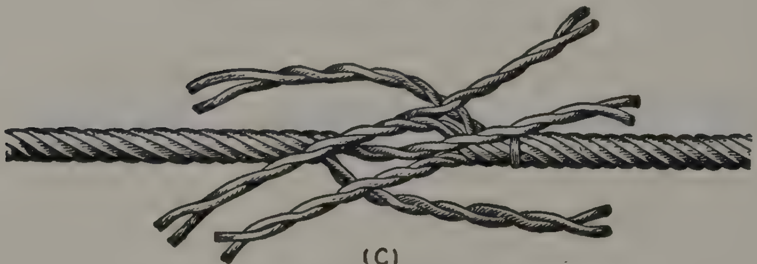
A2.7. Working in Wire Rope. As already stated, wire rope is usually six-stranded, with a hemp center. In splicing, we may work with the strands separately or in pairs. The work calls for special appliances and for a degree of skill such as can be acquired only by long practice under expert instruction. Something may be learned from careful description and much more from an occasional visit to a rigging loft; but the facilities which are available on shipboard do not permit doing such work as is possible with a rigger's bench, a turning-in machine, etc. Where a heavy rope is to be bent around a thimble or the parts otherwise brought together for splicing or seizing, a rigger's screw is needed. In the absence of this, a vise may be used, but less conveniently.

In tucking the strands of a splice, the lay of the rope is opened out and the spike left in, holding the strands apart until the tuck has been made. For hauling the strands through, a jigger is used on each one, the body of the rope being held by another jigger or a lashing. After a tuck, the parts of the ropes

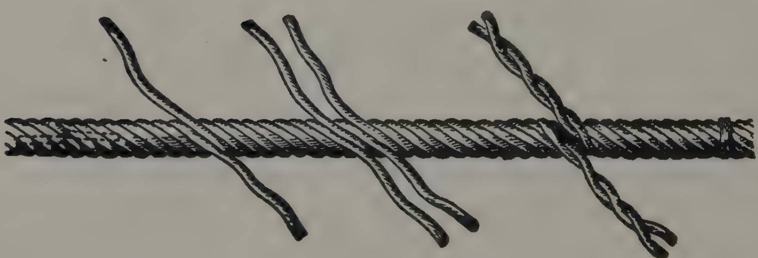


(A)
1st METHOD
LONG SPLICE IN WIRE ROPE (1)

(B)
1st METHOD
LONG SPLICE IN WIRE ROPE (2)



(C)
2nd METHOD
LONG SPLICE IN WIRE



(D)
2nd METHOD
LONG SPLICE IN WIRE

FIG. A2.9 LONG SPLICE IN WIRE

are hammered down tightly upon each other. Wire-cutters are used for cutting off ends.

A Long Splice in Wire (Fig. A2.9A and B). Put on a good seizing 6 to 10 feet—according to the size of the rope—from the end of one of the ropes to be spliced, and a similar seizing 1 to 2 feet from the end of the other rope. Unlay, open out the strands, cut out the center, and marry the ends together with strands interlacing. Cut the seizing on the short end. Unlay one of the short strands, following it up in the same lay with the opposite long strand, leaving end enough to tuck. Continue in the same manner with the remaining strands, except as to the distance to which they are laid up, this distance being varied in such a way as to leave the successive pairs an equal distance apart, as shown in Fig. A2.9B. Commencing with any two strands, half knot them together (full size), then divide each into three parts and tuck these parts separately as shown; or, cut out a few inches of the center and insert the ends of the strands in its place in the center of the rope. When a splice is to be served, the latter way of finishing it off answers very well.

Second Method (C and D). Will be clear from Fig. A2.9.

A Short Splice in Wire (Fig. A2.10). A. Put on a good seizing 2 or 3 feet, according to size of the rope, from the end of the ropes to be spliced, and a similar seizing 1 or 2 feet from the end of the other rope. Unlay the ends and open out the strands, cutting out the heart close to the seizings. Marry them together and clap on a temporary seizing around the short ends and the body of the rope, to hold the parts close together. Commencing with any one of the long strands, tuck each in succession over one and under two strands, opening out the lay with a spike. Tuck the remaining strands in the same manner; twice whole strands, once one half, and once one quarter, hauling through with a jigger each time. Then turn the splice around, cutting the temporary seizing on the short ends, and tuck the short strands once one half and once one quarter, heaving them through with a jigger. Hammer down all parts and trim off the ends.

An Eye Splice in Wire. B. Put the rope on a stretch, allow from 18 to 24 inches from the end for splicing, and put on a mark with a couple of turns of twine. Measure along the rope from this mark the length of the eye (one and one half the round of the thimble) and put on another similar mark. Paint with red lead, worm, parcel, paint again, and double-serve between the marks. Now come up the stretch and seize the thimble in, breaking the wire into the shape of the thimble, heaving both parts together with a rigging screw and putting a good racking seizing around both parts. Come up the screw, unlay the end of the wire, and cut out the heart close to the service. Now, with the thimble toward you, counting from left to right 1, 2, 3, etc., stick No. 4 (Fig. A2.10B) strand from right to left under the two upper strands of the rope just clear of the service, opening the strands by a spike. Haul through by hand. In the same manner—under two strands—tuck the remaining strands, in the following order: 3, 5, 2, 6, 1. Now, commencing with any strand, tuck again whole over one and

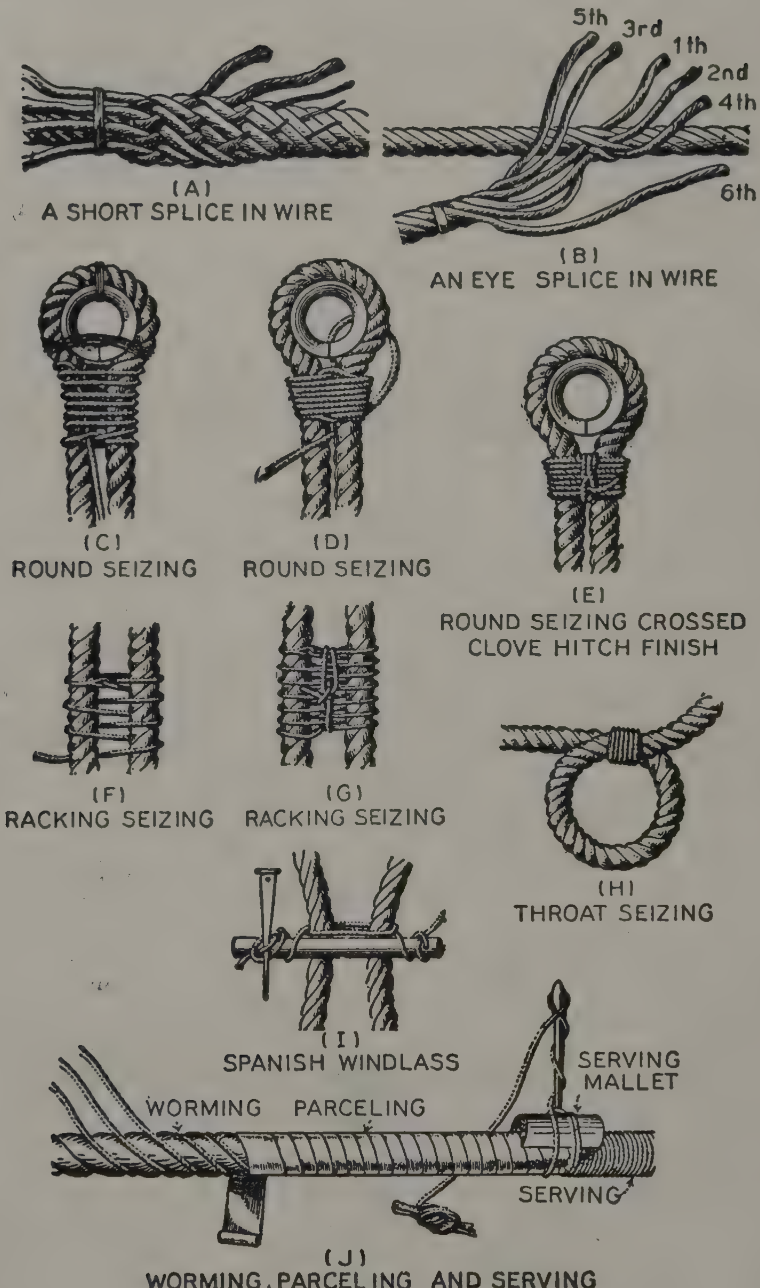


FIG. A2.10 SPLICES—SEIZINGS

under one and haul through by means of a jigger. Hammer the strands down in place, cut each strand down to two-thirds size and tuck again, hauling through with a jigger as before. Cut the strands down to one third and tuck again. Hammer down all strands and cut off the wire with a wire-cutter.

The eye splice is most often used on board ship. Expert riggers favor the following method of turning in this splice.

1st. Clap on a stout whipping from 1 to 4 feet from end of wire rope, depending upon its size.

2nd. Whip the end of each strand with strong sail twine. Unlay the strands and cut out heart (core) of rope (not of strands).

3rd. Break the eye around the thimble place in riggers screw and seize it in place, put the wire on a stretch at about waist height.

4th. With the strands lying about parallel to the part of the wire through which they are to be tucked, stand with the thimble away from you, bight of rope under your right arm.

5th. Open a way through the middle of the bight, spike horizontal, pointing away from you. This is easy when enough turn has been taken out of the bight by a heaver.

6th. Take top one of strands to be tucked, and shove it through the middle of the rope, following the spike which may be withdrawn as tucking strand goes through. When through, tuck this strand around the strand of bight lying above it.

7th. Take the next strand down through middle having opened the way again, but only under two strands, and around the strand lying just above it.

8th. Take next strand down through middle opening, but only under and around one strand.

9th. Now take the next strand (fourth), and tuck it over and around the next strand to the right.

10th. Take next one over and around the next.

11th. Take last strand over and around the last untouched strand on the bight.

Note: All strands are tucked around in the same direction that the wires run in the strand. Strands are then tucked once more, around and around, sailmaker fashion, then heart is taken out of strands and half of the wires are cut out and the splice is tucked twice more.

Finish the splice by parceling with tarred canvas and serve over all with marline.

A2.8. Wire-Rope Grommets. A popular method of laying up a grommet of wire is to use two strands, carefully unlaying them from the rope and keeping them in their normal position in relation to one another. The length of the two strands used is something more than three times the circumference of the grommet to be made. Form the grommet of the bight of a left-handed overhand knot. Lay each double end around in the lay of the bight until they meet. This will bring four ends together, with a pair pointing each way, and six

strands around the bight or grommet. Now cast off the seizing that holds the ends of the pair of strands together. Unlay one strand's end in the lay vacated as the strand was unlaid. This will separate the points of opposing parts, cross and tuck the ends in the same manner as in tucking the ends for a long splice.

Figure A2.10C, D, E, F, G, and H. Seizings for binding two ropes or two parts of the same rope. The manner of passing them is made clear by the figures. With heavy ropes, the parts must be hove together by power of some kind, such as a Spanish Windlass, a rigger's screw, or a turning-in machine.

A Spanish Windlass for Drawing Two Taut Ropes Together. I.

Worming, Parceling, and Serving. J. Rope which is to be exposed to the weather or to exceptionally hard usage is protected by worming, parceling, and serving.

Worming consists in following the "lay" of the rope, between the strands, with small-stuff tarred, which keeps moisture from penetrating to the interior of the rope, and at the same time fills out the round of the rope, giving a smooth surface for the parceling and serving.

Parceling consists in wrapping the rope spirally with long strips of canvas, following the lay of the rope, and overlapping like shingles on a roof to shed moisture.

Serving consists in wrapping small-stuff snugly over the parceling and is done against the lay of the rope. A "serving mallet" is used for passing the turns, each turn being hove taut by the leverage of the handle so that the whole forms a stiff protecting cover for the rope.

Mechanical Eye Splice. A method of making eye splices in wire rope by swaging a metal sleeve around the rope with a hydraulic press is now available. This mechanical splice is superior in appearance, is easier to make, and is stronger than a manual splice. No seizing is necessary for this splice and splices can be made in all sizes of wire rope from one-eighth inch to one and one-half inches in diameter.

A2.9. Appliances for Use with Wire Rope (Figs. A2.11 and A2.12). Most of the appliances for use with wire rope are designed to provide some sort of an eye on the end of the rope, by which it can be connected with another rope or with a tackle, or otherwise secured. Figure A2.11 illustrates a number of these. It will be seen that any two of the ends shown can be joined together, either directly or by the aid of a shackle. B shows a handy clip and the manner of applying it. These clips, when made of drop-forged steel and properly applied, are little if at all inferior to a splice, and they can be applied in a few moments where a splice would take as many hours. In the emergencies which sometimes arise on shipboard, as in handling anchors, taking a vessel in tow, etc., when an eye is needed in a hawser and there is not time to make a splice, these clips would be invaluable. They can be removed as quickly as they are applied, breaking down the eye at once.

A set of these in sizes to fit any hawser on board might well be issued to all ships. Note that the U-bolt is always applied to the "dead" end of the rope.

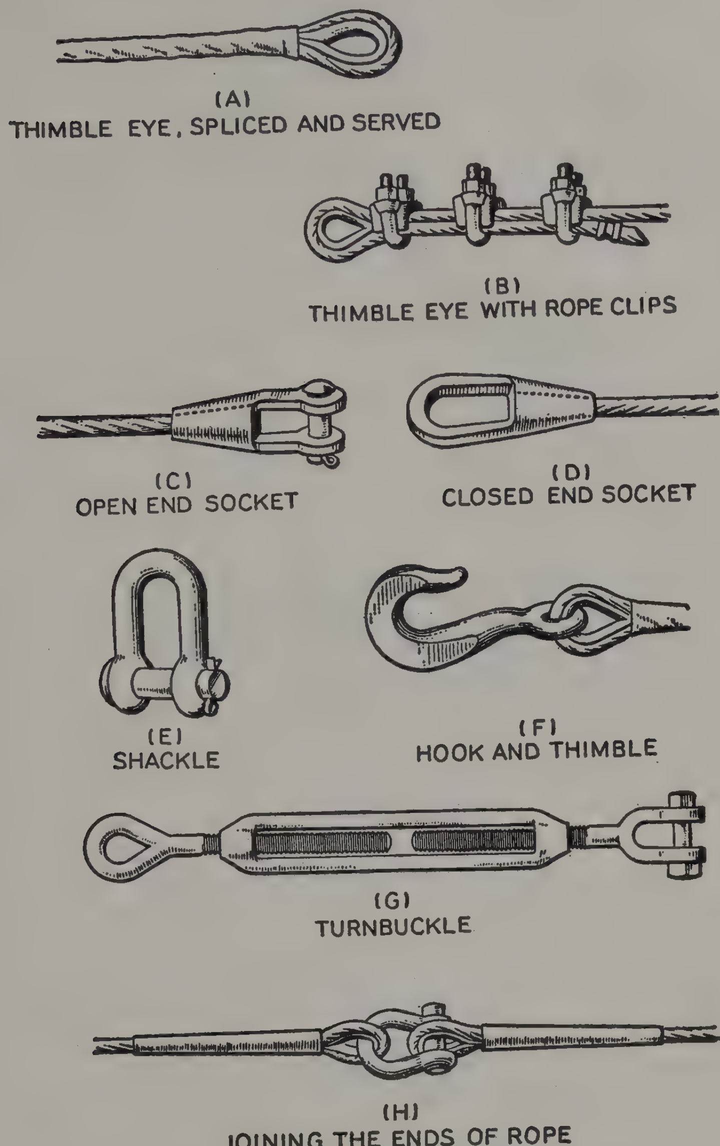


FIG. A2.11 APPLIANCES FOR USE WITH WIRE ROPE

Number of wire rope clips required to make a fastening having 80 percent of the strength of 6 x 19 plow steel wire rope.

Diameter of the Rope (Inches)	Number of Clips
¾	5
⅞	5
1	5
1⅛	5
1¼	6

The distance between clips should not be less than six times the diameter of the rope.

For wire rope smaller than ¾-inch diameter, at least four clips should be used.

For wire rope larger than 1¼ inches, it is preferable to socket the rope and avoid the use of clips.

Clips should be inspected daily and the bolts tightened, if they become loose as the rope stretches.

Sockets. Sockets are devices secured to the ends of wire rope to provide ready means for bending ropes together or to attach a load. Sockets are classed as open or closed, depending on whether they are the jaw and pin or loop types.

The rope end should be whipped (seized) near the end. Put on an additional seizing at a distance from the end of the rope equal to the length of the basket of the socket. It is very important that the seizings be secure to prevent untwisting of the wires and strands and a resultant unequal tension between the several wires after the socket is attached. Place the rope end upright in a vise. Remove the seizing at the bitter end. Cut out the hemp heart down to remaining seizing. If the heart is wire, allow it to remain. Untwist the strands and broom out the wire. The wires should be separated from each other but should not be straightened. Clean the wires carefully with benzine, naphtha, or gasoline, for the distance they will be taken into the socket; then dip them in a bath of commercial muriatic acid for 30 seconds to 1 minute, or until the acid has thoroughly cleaned each wire. To remove the acid, dip into boiling water containing a small amount of soda. Draw the wires together again (a piece of seizing wire will be suitable to do this) so that the socket can be forced down over them. Force the socket down over the rope end until it reaches the seizing. Free the wires within the socket basket and allow them to spread evenly and naturally. The ends of the wires should be level with the large end of the socket basket. Care should be taken to see that the centerline of the basket is lined up exactly with that of the rope, i.e., that the socket is in a true straight line with the rope, so that when under load each element will sustain its due share. Seal the small end of the socket around the rope with putty, clay, or similar substance. Fill the socket basket with molten zinc. The zinc must not be too

hot, particularly on small ropes. From 800 degrees to 850 degrees F is the correct temperature. Allow to cool in air or by plunging into cool, fresh water. Remove the seizing and the socket is ready for service.

The socket shown in Fig. A2.11C and D is the strongest attachment known for use on the end of a wire rope. The interior of the base of the socket is coned and the bare end of the rope is bedded in and sealed with molten zinc, which forms a head that holds without distortion of the wires.

Figure A2.12 shows a wire clamp that is very handy and of great strength. The rigger's screw is invaluable in splicing and working fittings on wire rope.

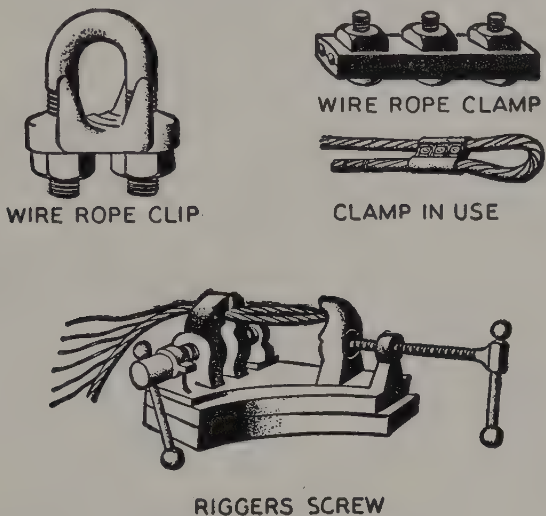


FIG. A2.12 RIGGER'S SCREW

APPENDIX

3

Mechanical Weight Lifting Appliances Aboard Ship

The advent of nuclear power afloat has not relieved seamen of the necessity of understanding the same fundamental knowledge of ropes, tackles, and weight handling that was required of their predecessors. True, the weights are heavier, are moved greater distances, and wire or wire rope is used now, but the same principles of mechanical advantage and friction still apply.

Tasks requiring the use of booms, tackles, topping lifts, and other mechanical appliances are the daily lot of seamen. Merchant vessels and naval cargo types require the rigging of many different purchases for positioning and steadying the cargo booms and for handling the weights after the booms have been rigged. Naval vessels of all types employ chain hoists and small tackles to load, strike below, and break out stores and ammunition.

Anyone who is concerned with rigging or operating cargo booms should be thoroughly familiar with the forces which are set up during the operation. To this end, he should consult the manufacturer's tables to determine the strength of the wire or rope used in the standing and running rigging, and he should never exceed these loads. He should inspect all the rigging periodically, replacing worn parts and performing such preventative maintenance as may be specified by the manufacturer. Finally, he should be familiar with the fundamentals of applied mechanics and the effects of acceleration and deceleration on the rigging.

A3.1. Moving Weights. Most heavy weight handling on cargo vessels is done by means of one or more cargo booms. With the use of one boom the weight is lifted from its initial position, the boom swung until the weight is over its intended position, and the weight is lowered. This method is satisfactory only when light loads are being moved because the boom guys must be readjusted as the boom swings.

A more common method is the Yard and Stay rig in which two booms are used. One boom called the *hatch boom* is rigged to plumb the cargo hatch being worked, while the other, or outboard, boom is rigged over the side to plumb a lighter or the dock. Two winches and two cargo runners or whips are used,

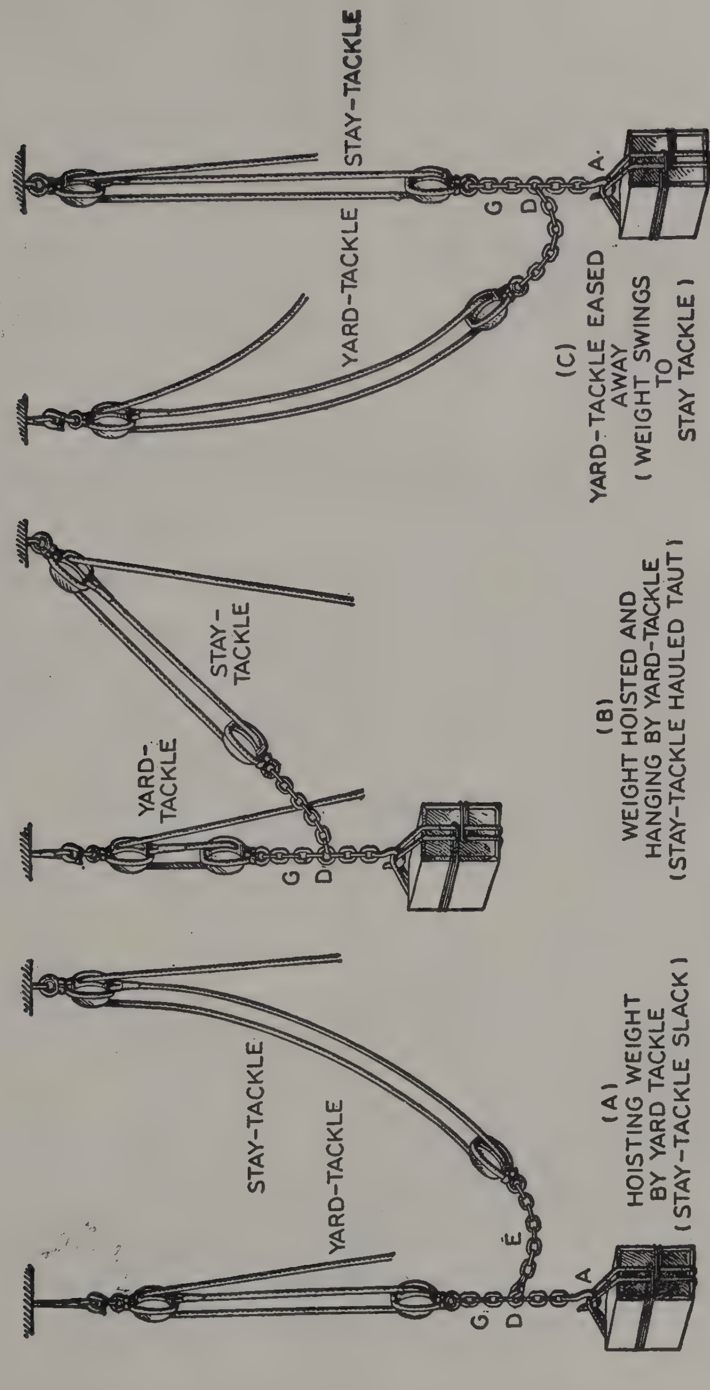


FIG. A3.1 YARD AND STAY TACKLES

one on each boom. Each runner is attached to a common hook which engages the load. For loading the winch of the outboard boom hoists the load, or draft, high enough to clear the ship's side or other obstruction. The draft is then "racked" inboard with the hatch boom winch heaving in and the other winch slacking off slowly until the load is entirely supported by the hatch boom. Finally, the hatch boom winch lowers the draft into the hold, with the outboard cargo runner being kept slack. For unloading, the cycle is reversed. See Fig. A3.1.

In any weight-handling operation speed should be subordinated to safety and smoothness of operation. Jerky movements caused by too rapid acceleration and deceleration put enormous strains on the standing and running rigging. This could result in the parting of one or more lines and the collapse of the entire rig with resulting damage to the load, the ship, and the operating personnel.

A3.2. Blocks. A "block," in the nautical sense, consists of a frame of wood or steel, within which is fitted one or more sheaves (pulleys).

Blocks take their names from the purpose for which they are used, the places they occupy, or from some peculiarity in their shape or construction. They are designated further as single, double, or triple blocks, according to the number of sheaves they have.

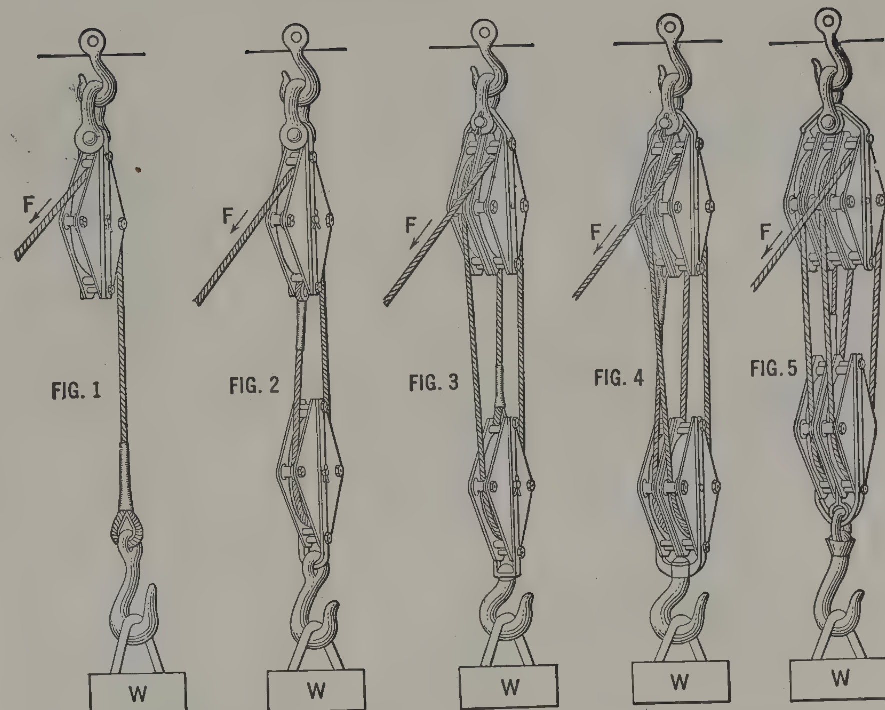
The size of the block is determined by the circumference of the rope to be used with it. For rope the size of the block in inches is three times the circumference of the rope; the diameter of the sheave is twice the circumference of the rope. Thus a block for use with a three-inch nylon rope would be (3 times 3) a nine-inch block, measured as the length of the cheek, and its sheave would be (2 times 3) six inches in diameter.

Blocks for use with wire rope are not so well standardized. Wire rope can be made to conform to widely varying specifications. When specifications for blocks are drawn, the advice of the manufacturer should be followed as to diameter of sheave or drum over which the wire is to be rove and the speed of operation (linear speed of the wire). If such advice is not followed, the life of the rope will be materially shortened due to alternate bending and straightening as the wire passes over the sheave (drum).

A3.3. Tackle. An assemblage of ropes (falls) and blocks for the purpose of multiplying force is a tackle (Figs. A3.2 and A3.3).

The seaman speaks of "reeving" when he passes ropes around the sheaves of the blocks. These ropes are called "falls." The "standing part" is that part of the fall made fast to one of the blocks. The hauling part is the end of the falls to which force is applied to handle the weight. To "overhaul" the falls is to separate the blocks. To "round in" is to bring the blocks together. The blocks are said to be "chock a block" or "two-blocked" when they are tight together.

Tackles are designated either according to the number of sheaves in the blocks that are used to make the tackle, e.g., single, two-fold, three-fold purchase; or according to the purpose for which the tackle is used, e.g., yard-



RATIO OF WEIGHT, W TO FORCE F NECESSARY TO RAISE WEIGHT.

	Disregarding Friction.	Allowing for Friction.
FIG. 1	$F = W$	$\frac{F}{W} = \frac{11}{10}$
FIG. 2	$\frac{F}{W} = \frac{10}{20}$	$\frac{F}{W} = \frac{12}{20}$
FIG. 3	$\frac{F}{W} = \frac{10}{30}$	$\frac{F}{W} = \frac{13}{30}$
FIG. 4	$\frac{F}{W} = \frac{10}{40}$	$\frac{F}{W} = \frac{14}{40}$
FIG. 5	$\frac{F}{W} = \frac{10}{50}$	$\frac{F}{W} = \frac{15}{50}$
In a three-fold purchase	$\frac{P}{W} = \frac{10}{60}$	$\frac{F}{W} = \frac{16}{60}$
Luff on Luff	$\frac{P}{W} = \frac{10}{120}$	$\frac{F}{W} = \frac{16}{120}$

Note: In this plate the hauling part leads from the fixed block. The mechanical efficiency can always be increased if the hauling part is led from the movable block.

FIG. A3.2 TYPES OF TACKLES

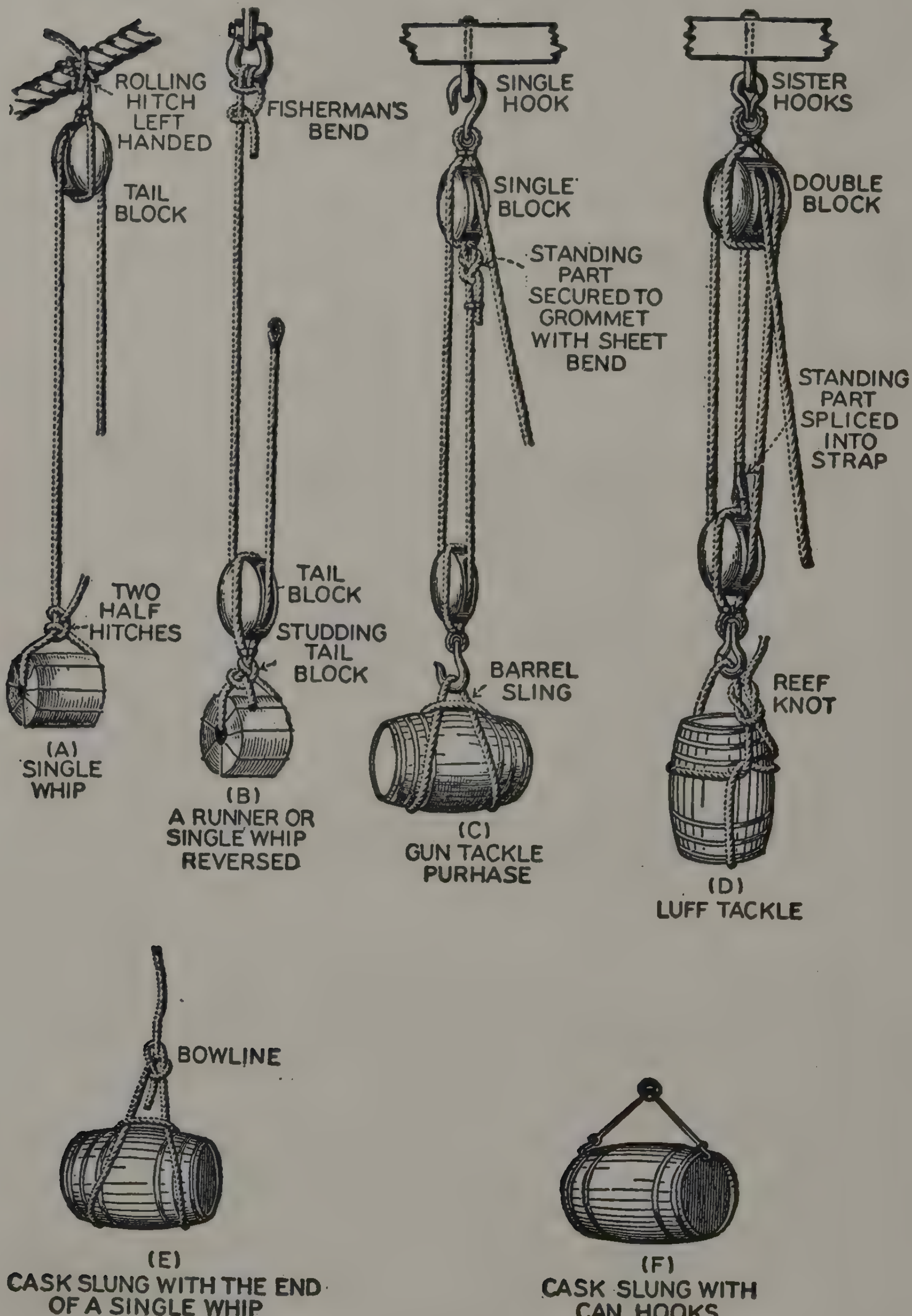


FIG. A3.3 TACKLES IN USE

tackles, stay-tackles, fore-and-aft tackles. Other designations handed down from the past still persist, as luff-tackles, gun-tackles, Spanish-burtons.

A single-whip. (A, Fig. A3.3.) A single block fixed.

A runner. (B, Fig. A3.3.) A single block movable.

A whip and runner would be a whip hooking to the hauling part of a runner.

A gun-tackle purchase. (C, Fig. A3.3.)

A luff-tackle. (D, Fig. A3.3.) A single and double block.

A luff upon luff. The double block of one luff-tackle hooked to the hauling part of another, thus multiplying the power.

A two-fold purchase. (Fig. 4, Fig. A3.2.) Two double blocks.

A double luff. A double and treble block. (Fig. 5, Fig. A3.2.)

A three-fold purchase. Two treble blocks. (See Fig. A3.4, in which two purchases are shown.)

A three-fold purchase is the heaviest purchase commonly used, designated by terms descriptive of their use without reference to the blocks or sheaves involved:

Thwartship-tackles are used on the heads of boat-davits for rigging in. In a more general sense the term is applied to any tackle leading across the deck. Similarly, a tackle for hauling out the backbone of an awning or for any other purpose where it has a fore-and-aft lead is a fore-and-aft tackle.

Hatch-tackles are used at hatches for hoisting, lowering stores, etc.

Jiggers are small light tackles used for miscellaneous work about the ship.

A deck-tackle is a heavy purchase, usually two-fold, used in handling ground-tackle, mooring ship, and generally for heavy work of any kind about the deck.

Yard and stay tackles take their names from their application on ships with masts and yards, where they were used together for transferring stores from a boat alongside to the deck or hatch of the ship. The general principle involved in the "yard and stay" is of wide application on merchant ships where a weight is to be lifted from a dock and lowered through a hatch on a vessel.

In the definition of tackle the phrase "for the purpose of multiplying force" is used. To explain the significance of this phrase it is necessary to use the basic formulae of work.

$$fS = Fs$$

This formula may be expressed as "a force times the distance through which it moves equals the weight (or resistance) times the distance through which it moves. In the formula, therefore, when used in connection with tackles, f represents a smaller force than F which is normally the weight being lifted and s is a smaller vertical height than S. Thus in a two-fold purchase if f acting through four feet (S) will raise a weight F one foot (s), we can write the fundamental equation:

$$f \times 4 = F \times 1$$

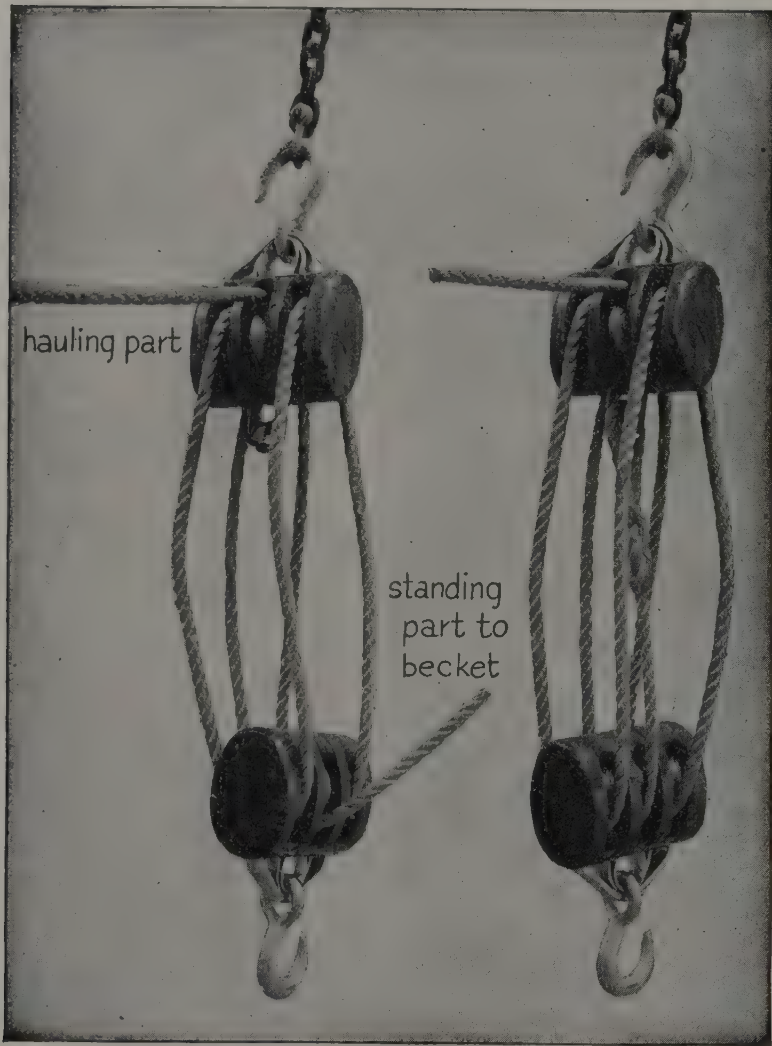


FIG. A3.4 RIGGING THE THREE-FOLD PURCHASE

or $f = F/4$, the force (f) has been multiplied four times. The mechanical advantage of this purchase is four.

A3.4. Chain Hoists (Fig. A3.5). Various types of chain hoists (mechanical purchases) are used on board ship. Inasmuch as the chain hoists are classified according to the weight they are built to handle, and their mechanical advantage is so designed that one man can pull enough force to lift the weight for which they are designed, no discussion of the mechanical principles of their design is given here. Suffice to say that if the weight for which a given chain hoist is designed is exceeded, disaster is invited. Overloading usually

FIG. A3.5 MECHANICAL PURCHASES

makes itself apparent by requiring an unusually heavy pull to raise the weight, by the weight hook spreading, or by the lifting chain parting. Overloading is to be carefully guarded against when using chain hoists as yard and stay tackles.

In a *differential purchase* (Fig. 6) an endless chain is taken over two sheaves of slightly different diameters which are keyed to the same shaft and revolve together. A movable block to which a weight may be attached is hung in the bight of the endless rope or chain. If force is applied to one of the parts leading from the larger sheave, the rope is unwound from the sheave but is at the same time wound up on the slightly smaller sheave alongside. Thus the change in the length of the bight which carries the movable block is very slight for a great distance moved by the hauling part. By a simple mathematical demonstration it can be shown that the ratio of the power applied to the power on the movable block is equal to the difference in the diameter of the sheaves of the fixed block divided by the larger diameter.

A *Duplex Purchase* (Fig. 5) consists of two wheels at right angles to each other, one of which has a cogged rim engaging a series of cams on the face of the other wheel. The details are made clear by the figure. The mechanical advantage here may be made almost anything that is desired by proper design of the cams and gearing. In any given case it may be determined theoretically (without friction) from the ratio of the distance moved by the power to that moved by the weight.

Still another type of chain hoist is illustrated in Figs. 1, 2, 3. This type is much used in the Navy.

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Page references in italic are to illustrations